Culminating Project

A Fire Protection Life Safety Analysis of Multipurpose Building

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Key Words:

Available Safe Egress Time (ASET) Required Safe Egress Time (RSET) Fire Dynamic Simulator (FDS) International Building Code (IBC) International Fire Code (IFC)
Life Safety Code (LSC) Performance-Based Design Prescriptive Based Design

Executive Summary

The following report is a fire and hazard protection analysis of a new building. This new building is a multi-purpose building called MPB locates in Gazipur, Dhaka, Bangladesh. The prescriptive requirements set by the codes and standards used at time of construction of the building have been met. The building has been properly classified with respect to occupancy as S1, Group B and F-1 and construction Type I A Sprinklered. Appropriate designs for interior partitions and exterior wall have been identified. Interior finish requirements have been analyzed for a better understanding of aesthetics guidelines. Based on the sprinkler drawing calculations, the fire sprinkler system has an adequate supply of water from the water reservoir tank plus a fire pump was added to meet the demand of the standpipes & sprinkler. Some of the calculations presented did not add up and mistakes were found on the drawings after review. The fire alarm system using sprinklers as initiating devices give a full coverage to the safety of the building protecting the property and stored valuables. Egress components are satisfactorily arranged for this low occupant building, but there is an issue with the egress capacity from the 3rd floor to stairwell, which is less than the required to code & standard.

A performance based analysis has been conducted. Activation of the fire suppression within the storage unit is the goal of the performance based analysis to confirm if the prescriptive requirements are enough to protect the storage unit, what is within the unit and the building itself. Fire scenario 6 from NFPA 101, Life Safety Code, was chosen. This fire was modeled by burning cotton fabric storage and polyester fuel stored separately inside a rack storage unit that can potentially be full of different items of clothing. The result of this study found that the ASET, available safe egress time, exceeded the RSET, required safe egress time. Overall this building is different in the fact that the overall goal is to protect the building itself not to protect the property inside the building. Only a handful of occupants will be present at any given time and they will have time to evacuate the building with enough time. The fire model is proof that in a scenario where a cotton / polyester fuel begins to burn inside a unit, the sprinkler system will activate leading the emergency team to respond.

Recommendations for this building are to reduce the occupant load from the factory occupancy on the second floor to the stairwells. Also it is recommended that different occupant load factors be used for the storage units to prepare for the worst case scenario instead of a N/A “value”. Lastly, it is recommended that the fire suppression drawing be updated in AutoCAD.

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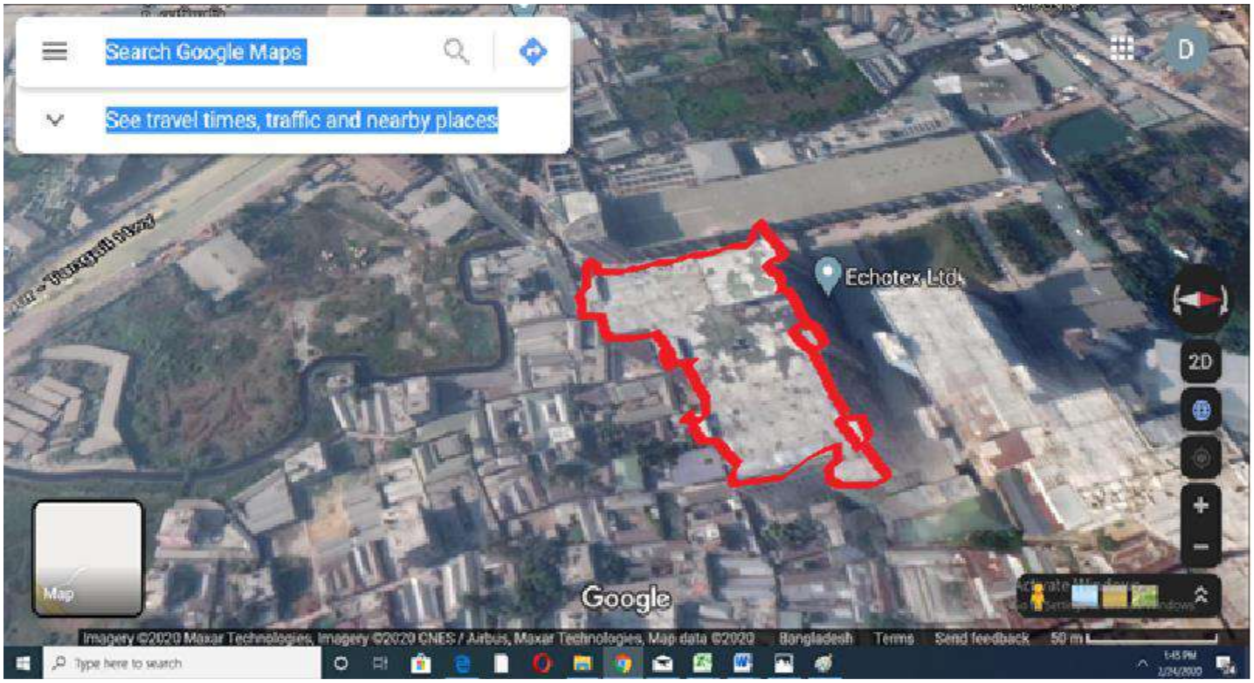
1.1 Introduction

The MPB building is a six story building located in Gazipur, Dhaka, Bangladesh (Fig#2). The gross floor area per story of the construction warehouse is around 70,000 ft^2. This building is used as a warehousing facility in support of a large construction project. Rack storage, which is moderate hazard occupancy, is permitted in this facility to a height of 11 ft. under a 15 ft. ceiling on 2^{nd}, 3rd, 4th & 5^{th} floor (See Fig#1). The Ground floor a factory floor and the 1^{st} floor has knitting & swing section, storage section and inspection area. It is classified as a mixed occupancy used for moderate storage (S-1), business (B) and Factory (F-1) purposes.

This facility was designed to provide over 210,000 square feet of warehouse space to approximately 726 employees from 2^{nd} to 5^{th} floor and other floor are mostly factory facility. The building was constructed of protected non-combustible (Type I-A) building materials and construction was started in late 2015.

Fig#1: Photo of MPB building.

An assessment of MPB's fire and life safety systems was performed to ensure these systems were designed and installed in a manner that meets, or exceeds, the intent of pertinent building codes and fire safety standards. This assessment included a prescriptive based analysis, as well as a performance-based analysis.

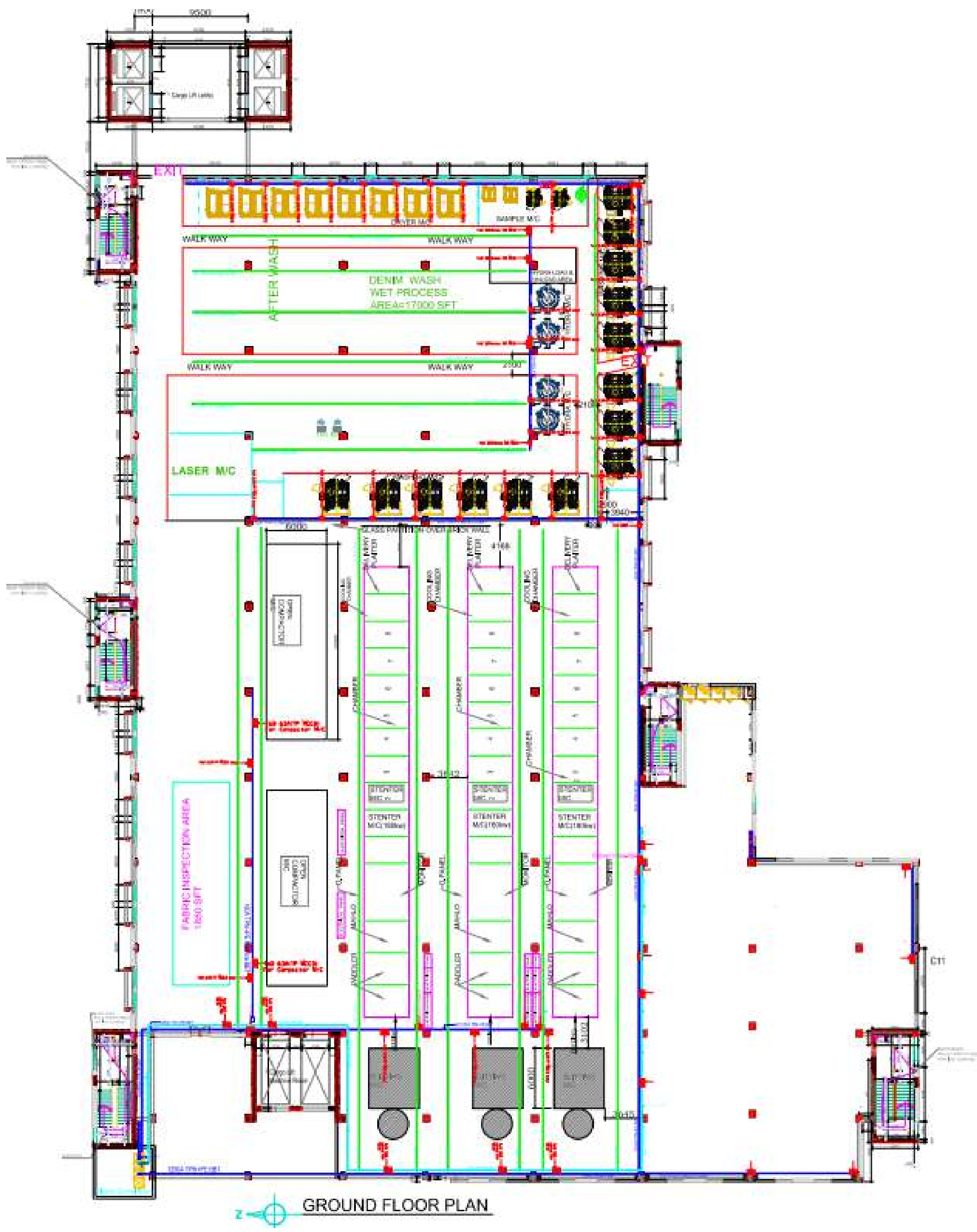


Fig#2: Aerial View of MPB Building.

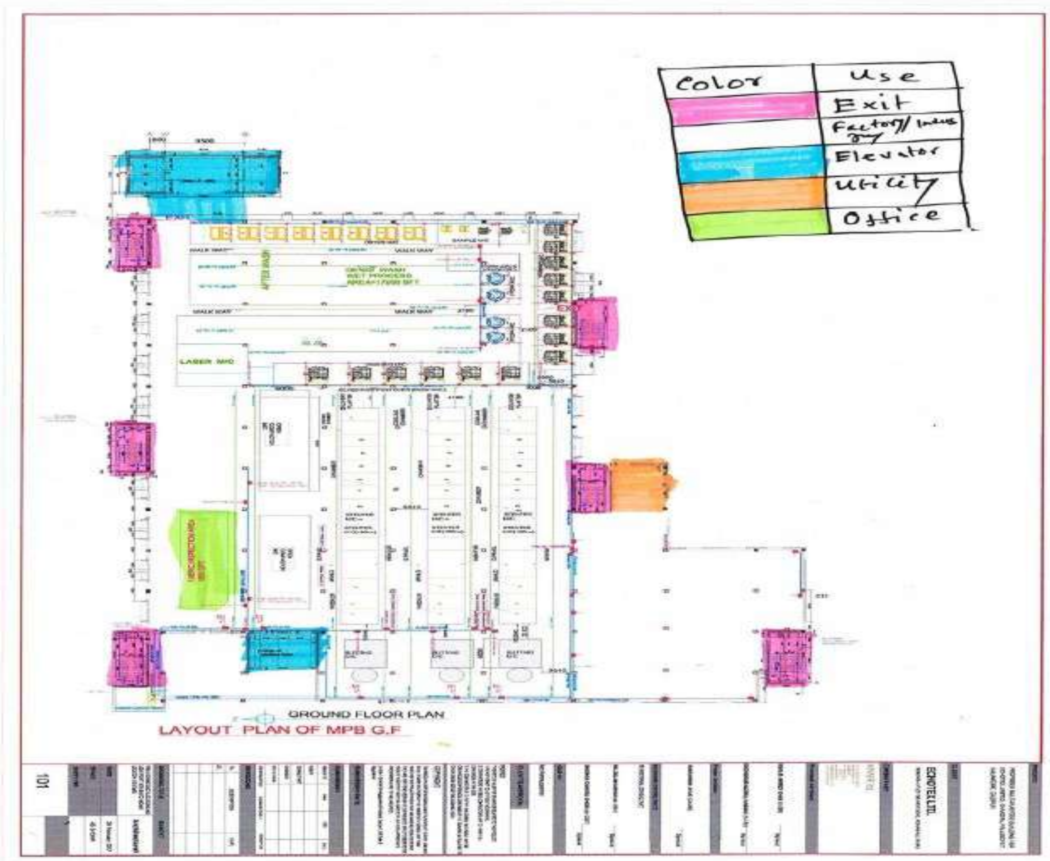
1.2 Occupancy Classification

The MPB's occupancy classification is based upon the requirements of the *2018 Internal Building Code (IBC)*. In accordance with this code, the intended use of each portion of the building was individually assessed and assigned an occupancy classification. The majority of the building is used for storage and factory space which are considered Storage S-1 and Factory F-1 Occupancy. The facility is designed Factory F-1, Business B and utility occupancy in Ground, 1st & 2nd floor.

In addition to aforementioned occupancies, Ground floor also has 2-hour fire rated electrical room beside the stair. The other (3rd, 4th and 5th) floors consist of Storage S-1, Business B and Utility Occupancies (see Fig#3, 3A, 3B, 3C, 3D & 3E).



Fig#3: Layout Plan of MPB Ground Floor.



Fig#3A: MPB's Occupancy Classification by Ground Floor.

Fig#3B: MPB's Occupancy Classification by 4st Floor.

Fig#3C: BPB's Occupancy Classification by 3rd Floor.

Fig#3D: BPB's Occupancy Classification by 5th Floor.

Fig#3E: MPB's Occupancy Classification by 1st Floors.

1.3 Separation Requirements

The IBC does not require separation between accessory occupancies and the main occupancy. However, one of the requirements of an accessory occupancy is that the accessory shall not occupy more than 10 percent of the floor area of the building story it is located on. Consequently, it must be separated from adjacent occupancies by walls with an appropriate fire resistance rating in accordance with Table 508.4 (see Table 1). Since the MPB building is equipped throughout with an automatic sprinkler system, no fire rated separation is required.

Table 1: IBC Occupancy Separation Requirements

REQUIRED SEPARATION OF OCCUPANCIES (HOURS)[f]

OCCUPANCY	A, E		I-1[a], I-3, I-4		I-2		R[a]		F-2, S-2[b], U		B[e], F-1, M, S-1		H-1		H-2		H-3, H-4		H-5	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
A, E	N	N	1	2	2	NP	1	2	N	1	1	2	NP	NP	3	4	2	3	2	NP
I-1[a], I-3, I-4	—	—	N	N	2	NP	1	NP	1	2	1	2	NP	NP	3	NP	2	NP	2	NP
I-2	—	—	—	—	N	N	2	NP	2	NP	2	NP	NP	NP	3	NP	2	NP	2	NP
R[a]	—	—	—	—	—	—	N	N	1[c]	2[c]	1	2	NP	NP	3	NP	2	NP	2	NP
F-2, S-2[b], U	—	—	—	—	—	—	—	—	N	N	1	2	NP	NP	3	4	2	3	2	NP
B[e], F-1, M, S-1	—	—	—	—	—	—	—	—	—	—	N	N	NP	NP	2	3	1	2	1	NP
H-1	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	NP	NP	NP	NP	NP	NP
H-2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	1	NP	1	NP
H-3, H-4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1[d]	NP	1	NP
H-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP

S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.

NS = Buildings not equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.

N = No separation requirement.

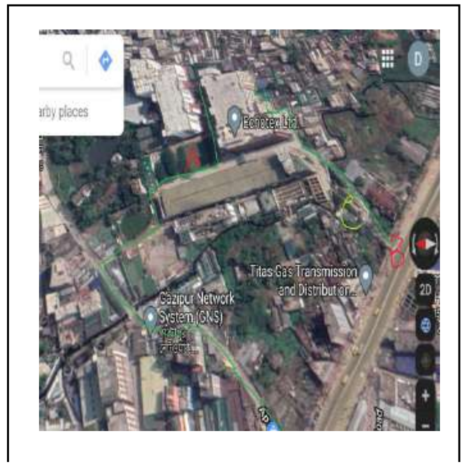
1.4 Construction Type

In accordance with IBC, buildings must be classified into one of five construction types. A building's intended use/ occupancy, height, area and construction material all affect the required construction classification. The construction classification will govern how a building is constructed and place various limitations on a building's design. However, some of these limitations can be reduced due to a building's frontage and the installation of an automatic fire suppression system.

A building's frontage is a measurement of the percent of the building's perimeter on a public way or open space. Buildings with larger frontage factors are assumed to provide more accessibility to fire/ emergency responders. An automatic fire suppression system is a fire protection device intended to autonomously mitigate/ extinguish a fire.

The following building characteristics were leveraged to determine the available construction types:

- Building Height = 111’-6”
- Number of Stories = 6
- Area per Story = 72000 ft^2
- Fully equipped with an automatic fire suppression system
- Majority of building has access to a public way or open space (see Fig#4).



Fig#4: Overhead View of MPB’s Frontage

In accordance with the 2015 IBC, a building’s height and area can be increased if the building is equipped throughout with an automatic sprinkler system. A building’s allowable area per story can also be increased if more than 25 percent of the building’s perimeter is exposed to a public way or open space.

Table 2 illustrates how these increases effected the types of construction permissible for the BPB building. NFPA 101®, Life Safety Code defines a high-rise building as a building more than 75 feet (23 meters) in height, measured from the lowest level of fire department vehicle access to the floor of the highest occupiable story. The **IBC** provides a **definition** for **high-rise** building as, “a **building** with an occupied floor located more than 75 feet (22,680 mm) above the lowest level of fire department vehicle access.”

As the MPB building is high rise, sprinkler system, structural fire protection system, fire detection system, emergency & exit lighting system, fire rated compartments along with fire rated exits system up to exit discharge meeting all other components from the code & standard , shall be provided.

1.5 Occupancy

The occupancy classification of the construction warehouse, per Chapter 3 and Chapter 5 (Section 508.4) of the IBC, is a "Mixed Use–Separated Occupancy" consisting of both Factory 'F-1', Moderate Hazard Storage 'S-1', Business 'B' occupancies.

1.6 Building Height and Area Limitations

Table 504 from the IBC provides the allowable area and height for a building containing Business and Storage occupancy groups.

TABLE 504.3
ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE[a]

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
S-1	NS	UL	11	4	2	3	2	4	3	1
	S	UL	12	5	3	4	3	5	4	2

1.7 Height Limitations

Per IBC Section 508.4.3, each separated occupancy is required to comply with the building height limitations based on the type of construction of the building.

Since the height of the warehouse from grade level to the last floor of the building roof is 111 ft., and since the height restriction from Table 503 for Type I-A construction is unlimited, the MPB building is limited as a Type I-A structure by its height.

1.8 Separation Requirements

Per IBC Table 508.4, a ‘B’ occupancy and ‘S-1’ occupancy do not require fire separation from one another. See Table 1.

The construction warehouse is allowed by the IBC to house “Mixed” B and ‘S-1’ occupancy without separation.

Table# 2: Types of Construction based on occupancy and sprinkler system.

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-1	NS	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
	S1	UL	UL	62,000	34,000	56,000	34,000	60,000	46,000	22,000
	SM	UL	UL	46,500	25,500	42,000	25,500	45,000	34,500	16,500
B	NS	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
	S1	UL	UL	150,000	92,000	114,000	76,000	144,000	72,000	36,000
	SM	UL	UL	112,500	69,000	85,500	57,000	108,000	54,000	27,000
E	NS	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
	S1	UL	UL	106,000	58,000	94,000	58,000	102,000	74,000	38,000
	SM	UL	UL	79,500	43,500	70,500	43,500	76,500	55,500	28,500
F-1	NS	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
	S1	UL	UL	100,000	62,000	76,000	48,000	134,000	56,000	34,000
	SM	UL	UL	75,000	46,500	57,000	36,000	100,500	42,000	25,500
F-2	NS	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
	S1	UL	UL	150,000	92,000	114,000	72,000	202,000	84,000	52,000
	SM	UL	UL	112,500	69,000	85,500	54,000	151,500	63,000	39,000
S-1	NS	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
	S1	UL	192,000	104,000	70,000	104,000	70,000	102,000	56,000	36,000
	SM	UL	144,000	78,000	52,500	78,000	52,500	76,500	42,000	27,000

1.9 Allowable Increases - Automatic Fire Suppression

The construction warehouse is fitted with a supervised automatic fire sprinkler system in accordance with NFPA 13 *Standard for Installation of Sprinkler Systems*.

According to IBC Section 504.2, 504.2 where a building is equipped throughout with an approved automatic sprinkler system, the value specified in Table 503 for maximum building height is increased by 20 feet (6096 mm) and the maximum number of stories is increased by one.

Also, according to IBC Section 506.3, the warehouse building area limitation in Table 503 is permitted to be increased by an additional 200 percent (I_c = 2 [see equation 5 — 1 below]) for buildings with more than one story above grade plane. These increases are permitted in addition to the height and story increases in accordance with Section 504.2.

1.10 Allowable Increases - Frontage

The frontage an all sides of the building is open and in excess of 30 feet.

The allowable building area shown in Table 503 may be increased according to IBC Section 506.2 According to the following equation:

$A_a = \{A_t + [A_t \times I_f] + [A_t \times I_c]\}$ (Equation 5-1)

Where: $A_a \equiv$ Allowable building area per story (ft^2)

$A_t \equiv$ Tabular building area per story in accordance with Table 503 (ft^2)

$A_{t\text{–}B}$ = Unlimited,

$A_{t\text{–}S1} = 48000\ ft^2$.

For Type I-B construction $I_f \equiv$ Area increase factor due to frontage as calculated according to: $I_f = [{}^{F}/_{P} — 0.25]\ {}^{W}/_{30}$

Where: F ≡ Building perimeter that fronts on a public way or open space having 20 feet open minimum width (ft).

F = 2 x building width + 2 x building length.

F = 2 x 255ft + 2 x 325ft

[F = 1160ft]

P ≡ Perimeter of entire building (ft) [P = F = 1160ft]

W ≡ Width of public way or open space (ft) in accordance with Section 506.2.1[W = 30 ft]

$I_f = [{}^{1160}/_{1160} — 0.25]\ {}^{30}/_{30}$

$I_f = 0.75$

$I_c \equiv$ Area increase factor due to sprinkler protection $I_c = 2$

For a ‘B’ (Business occupancy):

A_{a-B} = Unlimited area.

For a ‘F’ (Factory occupancy):

A_{a-B} = Unlimited area.

For a ‘S-1’ (Moderate hazard storage occupancy):

$$A_{a-S1} = \{48000\mathrm{ft}^2 + [48000\mathrm{ft}^2 \text{ x } 0.75] + [48000\mathrm{ft}^2 \text{x } 2]\}$$

$$A_{a-S1} = 180000\ \mathrm{ft}^2$$

- Table#3 (IBC Table 601) lists the following rating requirements for this type of building. MPB Building meets these requirements. 3 hour exterior walls
- 3 hour structural frame
- 1-1/2 hour floor/ceiling/roof protection

Table #3: Fire-Resistance Rating Requirements for Building Elements

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a,b]	2[a,b]	1[b]	0	1[b]	0	HT	1[b]	0
Bearing walls Exterior[a,f] Interior	 3 3[a]	 2 2[a]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	1 1/2[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

Occupancy Classification of MPB building is S1-Moderate Hazard Storage, Group-B Business and Factory F-1. Fire-resistance rating requirements for exterior walls based on fire separation distance are presented on Table #4. Here it states that based on MPB building occupancy classification there must be a 30 feet distance separation from other buildings in order to not have a required fire resistance rating.

Table# 4: Fire Resistance Requirements for Exterior Walls Based on Fire Separation Distance.

TABLE 602
FIRE-RESISTANCE RATING REQUIREMENTS FOR EXTERIOR WALLS BASED ON FIRE SEPARATION DISTANCE[a, d, g]

FIRE SEPARATION DISTANCE = X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP H[e]	OCCUPANCY GROUP F-1, M, S-1[f]	OCCUPANCY GROUP A, B, E, F-2, I, R[i], S-2, U[h]
X < 5[b]	All	3	2	1
5 ≤ X < 10	IA	3	2	1
	Others	2	1	1
10 ≤ X < 30	IA, IB	2	1	1[c]
	IIB, VB	1	0	0
	Others	1	1	1[c]
X ≥ 30	All	0	0	0

For SI: 1 foot = 304.8 mm.

a. Load-bearing exterior walls shall also comply with the fire-resistance rating requirements of Table 601.
b. See Section 706.1.1 for party walls.
c. Open parking garages complying with Section 406 shall not be required to have a fire-resistance rating.
d. The fire-resistance rating of an exterior wall is determined based upon the fire separation distance of the exterior wall and the story in which the wall is located.
e. For special requirements for Group H occupancies, see Section 415.6.
f. For special requirements for Group S aircraft hangars, see Section 412.3.1.
g. Where Table 705.8 permits nonbearing exterior walls with unlimited area of unprotected openings, the required fire-resistance rating for the exterior walls is 0 hours.
h. For a building containing only a Group U occupancy private garage or carport, the exterior wall shall not be required to have a fire-resistance rating where the fire separation distance is 5 feet (1523 mm) or greater.

The adjacent building is greater than 30 ft. which meets the above requirements.

2.1 Prescriptive Analysis

According to Section 4.4.2.1 of NFPA 101, a prescriptive-based life safety design must be in accordance with Chapters 1 - 4, Chapters 6 - 11, Chapter 38, 40 & 42, as well as, applicable occupancy Chapters. Since portions of the MPB building are classified as either Business Occupancy Group B or Industrial Group F-1 and Storage occupancy S-1 of NFPA 101 , 2018.

The prescriptive approach in this project includes an analysis of the following issues/systems:

- Fire Resistance;
- Prescriptive Structure Design

- Fire Detection, Alarm and Communication Systems;
- Flammability;
- Fire Suppression; and
- Egress.

2.2 Fire Resistance Requirements

The construction of MPB building is Type I-A Construction. So, the building's structural elements were required to meet a minimum fire resistance rating. However, specific portions of the building must be separated from adjacent areas by fire resistive materials. These areas include the following:

- Stairwells (2 hour partition);
- Elevator Shafts (2 hour partition);
- Exit Passageways (2 hour Protection).

The minimum fire resistive rating for the enclosure of floor openings shall be as follows (see 7.1.3.2.1 for exit enclosure) of NFPA 101, 2018 (8.6.5*).

1. Enclosures connecting four or more stories in new construction -2 hour fire rating.
2. Other enclosures of new construction -1 hour fire rating.
3. Existing enclosures of existing building -1/2 hour fire rating.

The IBC considers both stairwells and elevator shafts to be shaft enclosures. In accordance with IBC Section 713.4, "Shaft enclosures shall have a fire-resistance rating of not less than 2 hours where connecting four stories or more and not less than 1 hour where connecting less than four stories." Since the stairwells and elevator shafts in the MPB connect six stories, they were constructed as fire barriers with a fire resistance rating of 2 hours.

Section 1022.1 of the IBC, prohibits the level of protection provided by an exit to be reduced until the point of exit discharge. Exit passageways with a 2-hour fire-resistance rating were installed in the MPB to facilitate a protected path of egress from any connected stairwell until arrival at the exit discharge.

2.3 Opening Protective:

Every opening in a fire barrier shall be protected to control the spread of fire from the one side of the fire barrier to the other side according to Table#5 {NFPA 101, 2018 (8.3.3),Table 8.3.3.2.2 } prescribed the required fire rating.

Table 5: Fire rating of opening protective (8.3.3.2.2).

Table 8.3.3.2.2 Minimum Fire Ratings for Opening Protectives in Fire Resistance–Rated Assemblies and Fire-Rated Glazing Markings

Component	Walls and Partitions (hr)	Fire Door Assemblies (hr)	Door Vision Panel Maximum Size (in.^{2})	Fire-Rated Glazing Marking Door Vision Panel	Minimum Side Light/Transom Assembly Rating (hr)		Fire-Rated Glazing Marking Side Light/Transom Panel		Minimum Fire-Rated Windows Rating[a,b] (hr)		Fire-Rated Window Marking	
					Fire protection	Fire resistance	Fire protection	Fire resistance	Fire protection	Fire resistance	Fire protection	Fire resistance
Elevator hoistways	2	1½	155 in.^{2} [c]	D-H-90 or D-H-W-90	NP	2	NP	D-H-W-120	NP	2	NP	W-120
	1	1	155 in.^{2} [c]	D-H-60 or D-H-W-60	NP	1	NP	D-H-W-60	NP	1	NP	W-60
	½	⅓	85 in.^{2} [d]	D-20 or D-W-20	⅓	⅓	D-H-20	D-W-20	⅓	⅓	OH-20	W-30
Elevator lobby (per 7.2.13.4)	1	1	100 in.^{2} [a]	≤100 in.^{2}, D-H-T-60 or D-H-W-60 >100 in.^{2}, D-H-W-60	NP	1	NP	D-H-W-60	NP	1	NP	W-60
Vertical shafts (including stairways, exits, and refuse chutes)	2	1½	Maximum size tested	D-H-90 or D-H-W-90	NP	2	NP	D-H-W-120	NP	2	NP	W-120
	1	1	Maximum size tested	D-H-60 or D-H-W-60	NP	1	NP	D-H-W-60	NP	1	NP	W-60
Replacement panels in existing vertical shafts	½	⅓	Maximum size tested	D-20 or D-W-20	⅓	⅓	D-H-20	D-W-20	⅓	⅓	OH-20	W-30
Horizontal exits	2	1½	Maximum size tested	D-H-90 or D-H-W-90	NP	2	NP	D-H-W-120	NP	2	NP	W-120
Horizontal exits served by bridges between buildings	2	¾	Maximum size tested[e]	D-H-45 or D-H-W-45	¾[e]	¾[e]	D-H-45	D-H-W-45	¾	¾	OH-45	W-120
Exit access corridors[f]	1	⅓	Maximum size tested	D-20 or D-W-20	¾	¾	D-H-45	D-H-W-45	¾	¾	OH-45	W-60
	½	⅓	Maximum size tested	D-20 or D-W-20	⅓	⅓	D-H-20	D-H-W-20	⅓	⅓	OH-20	W-30
Other Fire barriers	3	3	100 in.^{2} [a]	≤100 in.^{2}, D-H-180 or D-H-W-180 >100 in.^{2}, D-H-W-180	NP	3	NP	D-H-W-180	NP	3	NP	W-180
	2	1½	Maximum size tested	D-H-90 or D-H-W-90	NP	2	NP	D-H-W-120	NP	2	NP	W-120
	1	¾	Maximum size tested[e]	D-H-45 or D-H-W-45	¾[e]	¾[e]	D-H-45	D-H-W-45	¾	¾	OH-45	W-60
	½	⅓	Maximum size tested	D-20 or D-W-20	⅓	⅓	D-H-20	D-H-W-20	⅓	⅓	OH-20	W-30
Smoke barriers[f]	1	⅓	Maximum size tested	D-20 or D-W-20	¾	¾	D-H-45	D-H-W-45	¾	¾	OH-45	W-60
	½	⅓	Maximum size tested	D-20 or D-W-20	⅓	⅓	D-H-20	D-H-W-20	⅓	⅓	OH-20	W-30
Smoke partitions[f,g]	1	⅓	Maximum size tested	D-20 or D-W-20	¾	¾	D-H-45	D-H-W-45	¾	¾	OH-45	W-60
	½	⅓	Maximum size tested	D-20 or D-W-20	⅓	⅓	D-H-20	D-H-W-20	⅓	⅓	OH-20	W-30

For SI units, 1 in.^{2} = 0.00064516 m^2.

NP: Not permitted.

In the same way, openings in interior exit stairway enclosures shall be in compliance with IBC Section 716. Table 6 (see Table 716.5) prescribes the required fire *protection* ratings for doors installed in interior exit stairways. So, stairwells and exit passageways in the MPB building are required to have a fire- *resistance* rating of 2 hours. However, the doors protecting these enclosures are only required to have a fire protection rating of 1.5 hours.

Table 6. IBC Fire Protection Rating Requirements for Opening Protective.

TYPE OF ASSEMBLY	REQUIRED WALL ASSEMBLY RATING (hours)	MINIMUM FIRE DOOR AND FIRE SHUTTER ASSEMBLY RATING (hours)	DOOR VISION PANEL SIZE	FIRE RATED GLAZING MARKING DOOR VISION PANEL[e]	MINIMUM SIDELIGHT/ TRANSOM ASSEMBLY RATING (hours)		FIRE-RATED GLAZING MARKING SIDELITE/TRANSOM PANEL	
					Fire protection	Fire resistance	Fire protection	Fire resistance
Fire walls and fire barriers having a required fire-resistance rating greater than 1 hour	4	3	Not Permitted	Not Permitted	Not Permitted	4	Not Permitted	W-240
	3	3[a]	Not Permitted	Not Permitted	Not Permitted	3	Not Permitted	W-180
	2	1½	100 sq. in.[c]	≤100 sq.in. = D-H-90 >100 sq.in.= D-H-W-90	Not Permitted	2	Not Permitted	W-120
	1½	1½	100 sq. in.[c]	≤100 sq.in. = D-H-90 >100 sq.in.= D-H-W-90	Not Permitted	1½	Not Permitted	W-90
Shaft, exit enclosures and exit passageway walls	2	1½	100 sq. in.[c, d]	≤100 sq.in. = D-H-90 > 100 sq.in.= D-H-T-or D-H-T-W-90	Not Permitted	2	Not Permitted	W-120

2.4 Prescriptive Structural Fire Protection.

The prescriptive approach is the traditional and still most commonly used method for fire engineering design. It aims solely to provide adequate levels of life safety to meet the fire resistance requirements specified in the national building regulations.

Structural fire resistance requirements are normally defined in terms of time periods during which a structure or structural member will perform adequately when assessed against the load bearing, insulation and integrity criteria.

The requirements for fire resistance for multi-story buildings are generally specified with regard to the use and height of the building, as shown in Table 2. Typically, the fire resistance requirements for multi-story buildings range from 60 minutes (R60) to 180 minutes (R180), but some national regulations may require up to 4 hours fire resistance (shown in Table 7 and Table 8). If a building is fitted with a sprinkler system, the fire resistance period required for the structural elements by prescriptive regulations may be reduced by 1-hour rating by IBC and NFPA. However, there is no reduction in fire protection prescribed in Bangladesh National Building code (BNBC) for the sprinkled buildings.

Table7: Fire Resistance Rating Requirements for Building (table 601, IBC)

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3^a	2^a	1	0	1	0	HT	1	0
Bearing walls Exterior[e, f] Interior	 3 3^a	 2 2^a	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	$1\frac{1}{2}^{b}$	$1^{b,c}$	$1^{b,c}$	0^c	$1^{b,c}$	0	HT	$1^{b,c}$	0

For SI: 1 foot = 304.8 mm.

Table 8: Bangladesh National building code fire resistance requirement (BNBC, table 3.3.1)

বাংলাদেশ গেজেট, অতিরিক্ত, নভেম্বর ১৫, ২০০৬

Table 3.3.1
Required Fire Resistance Ratings of Building Elements (in hours) for Various Types of Construction

Building Element	Type of Construction: Type 1	Type 2	Type 3
(1) Exterior bearing walls	4	2 (see Note a)	1
(2) Exterior nonbearing walls and curtain walls	2	1.5 (see Note a)	1
(3) Interior bearing walls, bearing partitions, columns, girders, trusses, (other than roof trusses) and framing			
(a) Supporting more than one floor	4	2	2
(b) Supporting one floor only or a roof only	3	1.5	1
(4) Structural frame and Structural members supporting wall	3	1.5 (see Note b)	1
(5) Floor construction including beams	3	1.5	1
(6) Roof construction, including beams, trusses and farming, arches and roof deck			
(a) 5m or less in height to lowest member	2	1.5	1
(b) More than 5m but less 7m in height to lowest member	1	1	1
(c) 7m or more in height to lowest member	0.5	0.5	0.5
(7) Fire walls and party walls	4	2 (see Note c)	2
(8) Enclosure of fire exits	2	2	2
(9) Shafts (other than exits) and elevator hoistways	2	2	2
(10) Access corridors leading to fire exits	1	1	1
(11) Vertical separation of tenant spaces	1	*1	1
(12) Nonbearing partition walls	0.5	0.5	0.5
(13) False/suspended ceilings	0.5	0.5	0.5
(14) Smoke barriers	1	1	1
(15) Mixed occupancy separation		(see Note d)	

Note : a : Not less than the rating based on fire separation distance (See Table 3.2.2)
b : Not less than fire resistance rating of wall supported
c : Not less than the rating required in Table 3.2.1
d : Fire resistance ratings of mixed occupancy separation, where permitted, shall as required in Table 3.2.1

STRUCTURAL FIRE PROTECTION REQUIREMENTS

The requirements for fire protection of the building structure and main elements are found in Table 601 of the IBC. For Type I-A construction, the primary structural frame of the building, as well as the interior and exterior load-bearing walls, must have a fire resistance rating of 3 hours. Floor construction and secondary members must have a rating of 2 hours, the roof construction and secondary members must have a rating of 1-1/2 hours, and nonbearing interior walls and partitions are not required to have a rating. Where the primary structural frame and bearing walls support a roof only, their rating is permitted to be reduced from 3 hours to 2 hours.

Qualification fire resistance testing in accordance with ASTM E119 is used extensively to satisfy building code requirements for fire resistance. In order to comply with fire resistance rating requirements, the architect or engineer usually selects suitable fire resistant designs from the UL Directory. Listed designs must be followed in every detail, in order to maintain the fire-resistance rating.

W/D Ratios: The rate of temperature rise in a structural steel member is a function of its thermal mass and the surface area exposed to heat. Therefore, the factor commonly us fire resistant design is the W/D ratio, where W is defined as the weight per foot of the steel member in pounds, and D is defined the heated perimeter of steel column in inches. Similar A/P ratios are used in the fire resistant design of tube column sections, where A is the section area in square inches and P is the section perimeter in inches (identical to D). Values of W/D and A/P ratios for various sections and configurations are tabulated in the AISC Steel Design Guide 19. The International Building Code and ASCE/SEI/SFPE 29 Standard Calculation Methods for Structural Fire Protection have many empirical correlations based on the W/D ratio to allow engineers to calculate the fire resistance of a particular steel section protected with different materials, including concrete, masonry, SFRM and gypsum board. The critical temperature of steel is often used as a benchmark for determining the failure of structural members exposed to fire. This ensures that the yield strength is not reduced to less than that of 50 % of ambient value. The critical temperature for various types of steels is given in Table#9 (reference SFPE Handbook Table 9.2)

Table#9: Critical temperature for various types of steel.

Table 9.2 Critical temperature for various types of steel

Steel	Standard/reference	Temperature (°C)
Structural steel	ASTM	538
Reinforcing steel	ASTM	593
Prestressing steel	ASTM	426
Light-gauge steel	EC 3 [51]	350
	Gerlich et al. [55]	400

Floor and Roof Construction: Fire rated restrained floor and roof assemblies will usually be selected to satisfy the fire resistance requirements for floor and roof construction including beams and joists. The International Building Code contains fire rating requirements for beams or girders that frame directly into a column. This is intended to ensure that columns remain braced against buckling during a fire. Fire rated floor and roof assemblies are listed under the D series designation of the UL directory. Structural Steel Columns IBC Table 719.1(1) prescribes many older column fire rated designs using generic materials, such as concrete, masonry, plaster and gypsum wallboard. Also, IBC Section 720.5.1 contains several equations (with W/D variable) and relevant tables for the calculation of fire resistance of steel columns protected with generic materials. Further, IBC Equation 7-13 allows the adjustment of thickness of proprietary SFRM materials based on the W/D ratio of the column section. ASCE/SEI/SFPE 29 standard contains very similar provisions for steel columns. In addition, the latter provides an equation for the determination of fire resistance of concrete filled tubular steel columns. Fire resistant steel column designs using proprietary materials, such as SFRM and intumescent coatings, are listed under the X and Y series designation of the UL directory.

Steel Trusses: The inherently large size of truss assemblies does not allow their adequate fire resistance testing in standard furnaces. However, several conservative approaches have been developed over the years for truss fire protection. One common approach is to protect each truss element to the same level as a column of a similar or smaller section size. Another conservative approach, sometimes used for lighter trusses, is to apply proven fire resistant joist designs to heavier trusses. Both approaches are based on the rationale that larger/heavier truss elements would heat up slower than smaller column sections or lighter joists under similar fire exposures. Individual Protection IBC section 713.2.1 requires that fire-rated columns, beams, girders, trusses and other structural members "shall be individually protected on all sides for the full length" where the structural element supports:

1. More than two floors or
2. More than one floor and one roof, or
3. A loadbearing wall, or
4. A non-loadbearing wall that is more than two stories high.

The requirement applies to most columns in multi-story buildings, and effectively prohibits protecting more than one column in a single fire protection enclosure. This individual protection requirement also prohibits the protection of "critical" beams, girders and trusses by fire rated ceilings. However, ceiling protection can be used for regular beam, girder or truss systems supporting one floor or transfer beams, girders and trusses supporting not more than two floors.

SFRM Thickness Adjustment:

The UL design will indicate the SFRM thickness that is required for a given fire rating. This thickness is valid only for the beam size that was tested. For instance, UL D739 was based on a W8x28 steel beam. Unless all of the beams on a project are W8x28s, the SFRM thickness will need to be adjusted for each beam size used. There is a simple formula that is used to calculate the required SFRM thickness based on the W/D or A/P ratio of the steel section.

$$h_2 = \left[\frac{(W_1 / D_1) + 0.6}{(W_2 / D_2) + 0.6} \right] h_1$$

Where h = thickness of SFRM

The project specifications should require the fireproofing contractor to submit W/D calculations for approval along with a schedule of fireproofing thickness for each beam and column size on the project.

Column fire protection:

The UL design will indicate the SFRM thickness that is required for a given fire rating. This thickness is valid only for the column size that was tested by UL X772 and UL X771 (from UL online certifications directory design no: X772 & X771, see Fig#5 & Fig#6).

h= R/((1.05(W/D)+0.61)

Where: h = Spray Applied Fire Resistive Materials thickness in the range 0.253.875 in.

R = Fire resistance rating in hours (1 4 h)

D = Heated perimeter of steel column in inches

W = Weight of steel column in lbs per foot

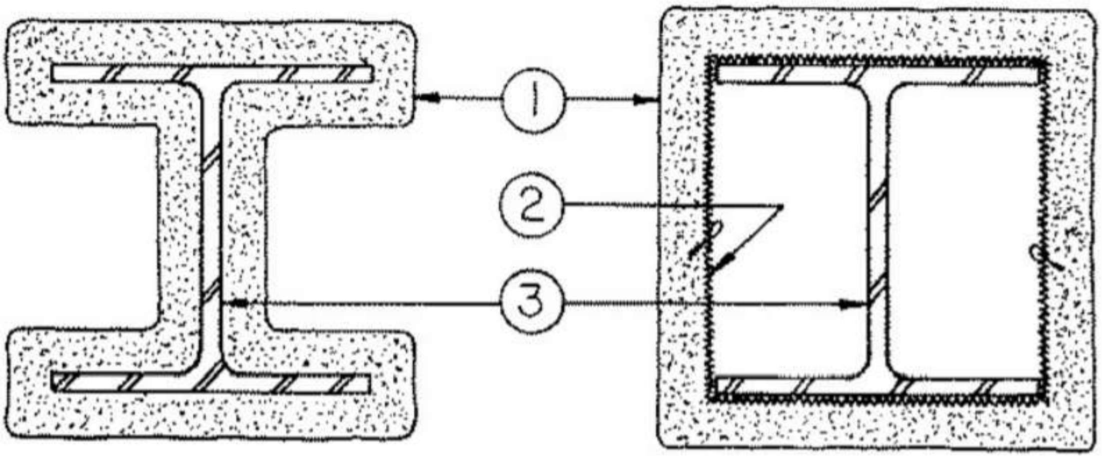
W/D = 0.33 to 6.62.

Design No. X772

August 17, 2015

Ratings — 1, 1-1/2, 2, 3 and 4 h.

Indicates such products shall bear the UL or cUL Certification Mark for jurisdictions employing the UL or cUL Certification (such as Canada), respectively.



1. **Spray-Applied Fire Resistive Materials*** — Applied by mixing with water and spraying in more than one coat to the thicknesses shown below, to steel surfaces which are clean and free of dirt, loose scale, and oil. Min avg and min ind density of 15/14 pcf respectively. Min avg and min ind density of 22/19 pcf respectively for Types Z-106, Z-106/G, Z-106/HY. Min avg and min ind density of 19/18 pcf respectively for Types 7GP and 7HD. Min avg and min ind density of 40/36 pcf respectively for Types Z-146, Z-146PC and Z-146T cementitious mixture. Min avg and min ind density of 50/45 pcf respectively for Types Z-156, Z-156T and Z-156PC. For method of density determination, see Design Information Section, Sprayed Material.

The thickness of Spray-Applied Fire Resistive Materials to be applied to all surfaces of the column (Item 1) required for rating periods of 1 h, 1-1/2 h, 2 h, 3 h, 4 h may be determined by the equation:

Fig5: Spray –Applied Fire Resistive Materials to UL design method X772

UL X771 TEST Method,

The hourly rating of the structural member is dependent upon the ratio of A/P and the thickness of SprayApplied Fire Resistive Materials, where A is the cross sectional area of the pipe or tube and P is the heated perimeter. The A/P ratio of a circular pipe is determined by:

$$A/P \text{ pipe} = \frac{t(d - t)}{d}$$

Where:

d = the outer diameter of the pipe (in.)

t = the wall thickness of the pipe (in.)

The A/P ratio of a rectangular or square tube is determined by:

$$A/P \text{ tube} = \frac{t(a + b - 2t)}{a + b}$$

Where: a = the outer width of the tube (in.)

b = the outer length of the tube (in.)

t = the wall thickness of the tube (in.)

The thickness of SprayApplied Fire Resistive Materials for ratings of 3/4, 1, 11/2, 2, 3 and 4 h of a steel pipe or tube can be determined by the equation:

$$\text{A/P tube} = \frac{t\,(a + b - 2t)}{a + b}$$

Where: R = the hourly rating (hrs).

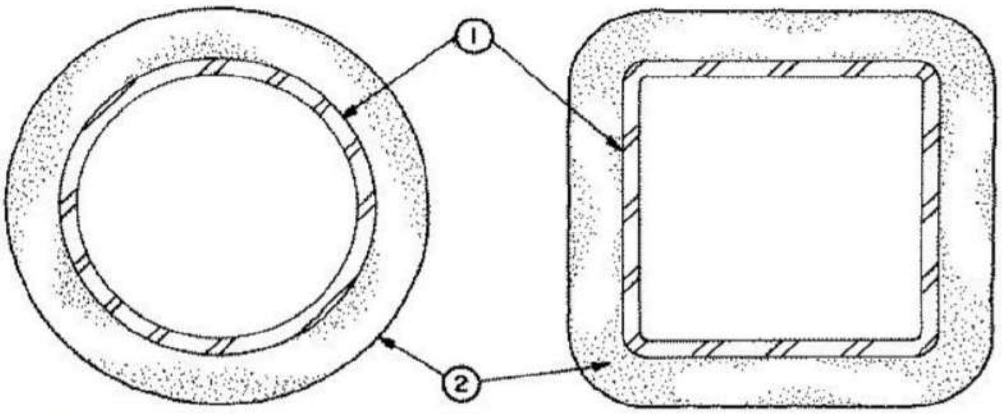
h = the thickness of SprayApplied Fire Resistive Materials, minimum 1/4 in., maximum 37/8 in.

Design No. X771

August 13, 2015

Ratings — 3/4, 1, 1-1/2, 2, 3 and 4 h

*** Indicates such products shall bear the UL or cUL Certification Mark for jurisdictions employing the UL or cUL Certification (such as Canada), respectively.**



1. **Steel Pipe or Tube Column —** Steel circular pipe with diameter (OD) ranging from a minimum of 3 in. to a maximum of 32 in. with a minimum wall thickness of 3/16 in.

Steel square or rectangular tube with outside wall dimensions ranging from a minimum 3 in. to a maximum of 32 in. and a minimum wall thickness of 3/16 in.

The A/P ratio of the steel pipe or tube (see Item 2) shall range from 0.18 to 2.0.

Fig#6: Spray –Applied Fire Resistive Materials to UL design method X771.

COLUMN CEMENTITIOUS FIRE PROTECTION:

Member designation	Type	Exposure	Web Depth mm	Web Thk mm	Flange width mm	Flange Thk mm	Hp	A	Hp/A	W/D	UL Design	Monokote Type	FRP	FP Thks mm	FRP	FP Thks mm
Wide Flange Beam Formula																
PG 450x450x352kg/m	Column-3	4	450	35	450	35	2630	44800	59	2.28	X772	MK-6/HY	3	25	4	34
PG 450x450x341kg/m	Column-4	4	450	20	450	40	2660	43400	61	2.18	X772	MK-6/HY	3	26	4	35
PG 450x450x307kg/m	Column-5	4	450	20	450	35	2660	39100	68	1.97	X772	MK-6/HY	3	29	4	38
PG 450x450x304kg/m	Column-6	4	450	30	450	30	2640	38700	68	1.96	X772	MK-6/HY	3	29	4	38
PG 400x400x301kg/m	Column-7	4	400	20	400	40	2360	38400	61	2.18	X772	MK-6/HY	3	26	4	35
PG 400x400x272kg/m	Column-8	4	400	20	400	35	2360	34600	68	1.96	X772	MK-6/HY	3	29	4	38
PG 450x450x261kg/m	Column-9	4	450	16	450	30	2668	33240	80	1.67	X772	MK-6/HY	3	32	4	43
PG 400x400x224kg/m	Column-10	4	400	20	400	30	2360	30800	77	1.74	X772	MK-6/HY	3	31	4	42
PG 400x400x231kg/m	Column-11	4	400	16	400	30	2368	29440	80	1.66	X772	MK-6/HY	3	32	4	43
PG 400x400x220kg/m	Column-12	4	400	12	400	30	2376	28080	85	1.58	X772	MK-6/HY	3	34	4	45
PG 350x350x201kg/m	Column-13															
PG 400x400x201kg/m	Column-14	4	400	16	400	25	2368	25600	93	1.45	X772	MK-6/HY	3	36	4	48
PG 400x400x190kg/m	Column-15	4	400	12	400	25	2376	24200	98	1.36	X772	MK-6/HY	3	37	4	50
PG 400x400x184kg/m	Column-16															
PG 350x350x166kg/m	Column-17	4	350	12	350	25	2076	21100	98	1.36	X772	MK-6/HY	3	37	4	50
PG 350x350x161kg/m	Column-18	4	350	10	350	25	2080	20500	101	1.32	X772	MK-6/HY	3	38	4	51
PG 400x400x160kg/m	Column-19	4	400	12	400	20	2376	20320	117	1.14	X772	MK-6/HY	3	42	4	56
PG 350x350x139kg/m	Column-20	4	350	12	350	20	2076	17720	117	1.14	X772	MK-6/HY	3	42	4	56
PG 350x350x134kg/m	Column-21	4	350	10	350	20	2080	17100	122	1.10	X772	MK-6/HY	3	43	4	58
PG 300x300x96kg/m	Column-22	4	300	10	300	16	1780	12280	145	0.92	X772	MK-6/HY	3	48	4	64
PG 200x200x37kg/m	Column-23															
PG 150x150x23kg/m	Column-24															
PG 300x300x127kg/m	**Column-25**	4	300	16	300	20	1768	16160	109	1.22	X772	MK-6/HY	3	40	4	54
PG 300x300x135kg/m	**Column-26**	4	300	20	300	20	1760	17200	102	1.31	X772	MK-6/HY	3	38	4	51
PG 300x300x123kg/m	**Column-27**	4	300	14	300	20	1772	15640	113	1.18	X772	MK-6/HY	3	41	4	55
PG 300x300x119kg/m	**Column-28**	4	300	12	300	20	1776	15120	117	1.14	X772	MK-6/HY	3	42	4	56
CH 150x75x14kg/m	Column-29															
CH 200x75x16kg/m	Column-30															

Member designation	Type	Exposure	Web thicknes mm	Web deptl mm	Flange width mm	Flange Thk mm	A/P	UL Design	Monokote Type	FRP	FP Thks mm	FRP	FP Thks mm
Build up Tube Column													
BG 450x450x428kg/m	Column-1	4	25	450	450	40	1.19	X771	MK-6/HY	3	13	4	18
BG 450x450x396kg/m	Column-2	4	25	450	450	35	1.10	X771	MK-6/HY	3	15	4	20

Beam fire protection by UL N782 Method:

UL N782 for a W8x28 beam coated with W. R. Grace Type MK-6 material.

A 3-hour restrained fire-rating is required. Therefore, a 1x in. (30.2 mm) thickness applied to the W8x28 test beam (W/D = 0.82) supporting all fluted floor units with lightweight concrete will be chosen.

W14x22, W/D = 0.53

Thickness of MK-6 materials applied to W14X22 beam is 1.49 inch shown below.

$$T_1 = \left(\frac{0.82+0.6}{0.53+0.6}\right) * 1.19 = 1.49$$

Beam Cementitious Fire Protection:

	Member designation	Type	Exposure	Web Depth (D) mm	Web Thk (tw) mm	Flange width (F1) mm	Flange Thk (T1) mm	Flange width (F2) mm	Flange Thk (T2) mm	Hp	A	Hp/A	W/D	UL Design	Product	FRP	Unrestrained FP Thks mm	FRP	Unrestrained FP Thks mm
	Wide Flange Beam Formula																		
Example	PG 600x300x200x160kg/m	Beam no-3	3	600	16	200	20	300	25	1968	20380	96.56526006	1.38	N782	MK-6/HY	3	26	4	36
	PG 600x300x200x143kg/m	Beam no-4	3	600	16	200	16	300	20	1968	18224	107.9894644	1.24	N782	MK-6/HY	3	28	4	39
	PG 600x250x200x135kg/m	Beam no-5	3	600	16	200	16	250	20	1868	17224	108.4533209	1.23	N782	MK-6/HY	3	28	4	39
	PG 600x150x150x117kg/m	Beam no-6	3	600	16	150	20	150	20	1618	14960	108.1550802	1.24	N782	MK-6/HY	3	28	4	39
	PG 300x300x300x96kg/m	Beam no-7	3	300	10	300	16	300	16	1480	12280	120.5211726	1.11	N782	MK-6/HY	3	30	4	42
	PG 600x210x150x82kg/m	Beam no-8	3	600	8	150	12	210	14	1754	9332	187.9554222	0.71	N782	MK-6/HY	3	39	4	54
	PG 600x210x150x80kg/m	Beam no-9	3	600	8	150	10	210	14	1754	9048	193.8549956	0.69	N782	MK-6/HY	3	40	4	55
	PG 600x200x150x79kg/m	Beam no-10	3	600	8	150	10	200	14	1734	8908	194.6564885	0.69	N782	MK-6/HY	3	40	4	55
	PG 600x200x140x75kg/m	Beam no-11	3	600	8	140	10	200	12	1724	8424	204.6533713	0.65	N782	MK-6/HY	3	41	4	57
	PG 400x200x200x71kg/m	Beam no-12	3	450	8	200	12	200	12	1484	8208	180.7992203	0.74	N782	MK-6/HY	3	38	4	53
	PG 450x200x140x63kg/m	Beam no-13	3	450	8	140	12	200	12	1424	7488	190.1709402	0.70	N782	MK-6/HY	3	39	4	55
	PG 300x250x150x59kg/m	Beam no-14	3	300	8	150	12	250	12	1234	7008	176.0844749	0.76	N782	MK-6/HY	3	38	4	52
	CH 200x75x16kg/m	Beam no-15	3																
	PG 600x300x200x226kg/m	Beam -1		600	16	200	20	300	25	1968	20380	96.56526006	1.38	N782	MK-6/HY	3	26	4	36
	PG 600x300x200x177kg/m	Beam -2		600	16	200	20	300	25	1968	20380	96.56526006	1.38	N782	MK-6/HY	3	26	4	36

Steel Column Concrete Encashment:

Steel Fire protection can be accomplished by concrete encasement according to IBC. The capacity of concrete to absorb heat is influenced by the moisture content of the concrete. Therefore, the fire resistance can be determined by equations in two steps. First, the fire endurance with zero moisture content is determined, and then that fire endurance is increased as a function of the actual moisture. IBC item 720.5.1.4 lists the equation for fire endurance at zero moisture as:

$$R_0 = 10\left(W/D\right)^{0.7} + 17\left(\frac{h^{1.6}}{k_c^{\ 0.2}}\right)x$$
$$\left[1 + 26\left(\frac{H}{\rho_c\, c_c\, h\,(L+h)}\right)^{0.8}\right]$$

Where

R_0 = Fire endurance rating at zero moisture content (min.)

W = Weight of steel column (lbs/ft)

D = Inside perimeter of the fire protection (in.)

h = Thickness of concrete cover (in.)

k_c = Ambient temperature thermal conductivity of concrete (Btu/hr ft °F)

H = Ambient temperature thermal capacity of the steel column = 0.11 W (Btu/ft °F)

ρ_c = Concrete density (pcf)

C_c = Ambient temperature specific heat of concrete (Btu/lb °F)

L = Interior dimension of one side of a square concrete box protection (in.)

Moreover, three more issues are required to be taken into account; they are described below (see Fig#7).

• When the inside perimeter of the concrete protection is not square, L shall be taken as the average of L1 and L2.

• When the thickness of the concrete cover is not uniform, h shall be taken as the average of h1 and h2.

• When the space between the flange tips and web is filled with concrete (i.e. full encasement), the thermal capacity of the steel column, H, can increased as follows:

$$H = 0.11\,W + \left(\frac{\rho_c\, c_c}{144}\right)\left(b_f\ d - A_s\right)$$

Where

b_f = Steel column flange width (in.)

d = Steel column depth (in.)

A_s = Steel column area (sq. in.)

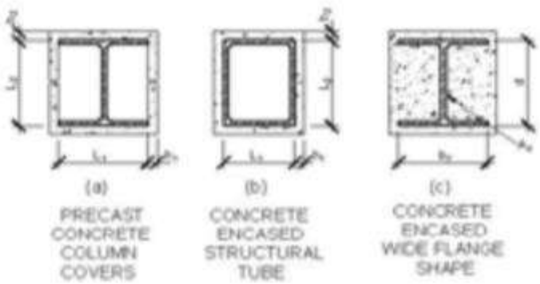
The fire endurance increases as the moisture content of the concrete increases. Therefore, the fire endurance at zero moisture is increased as follows

$$R = R_0\,(1 + 0.03\ m)$$

Where

R = Fire endurance rating at the actual moisture condition (min.)

m = Actual moisture content of concrete by volume (percent)



Fig# 7: Structural Steel Columns with Concrete Protection.

Example:

Determine if 3-hour fire endurance is provided by a W14x90 column encased with normal weight concrete, creating an 18 in. x 18 in. (457.2 mm x 457.2 mm) enclosure.

W = 90 lb/ft

D = 84.6 in.

W/D = 1.06

As = 26.5 in^2.

h = (h1 + h2) / 2 = (2+1.75) / 2 = 1.88 in.

k_c = 0.95 Btu/hr ft °F

ρ_c = 145 pcf

c_c = 0.20 Btu/lb °F

L = (L1 + L2) / 2 = (14+14.5) / 2 = 14.25 in.

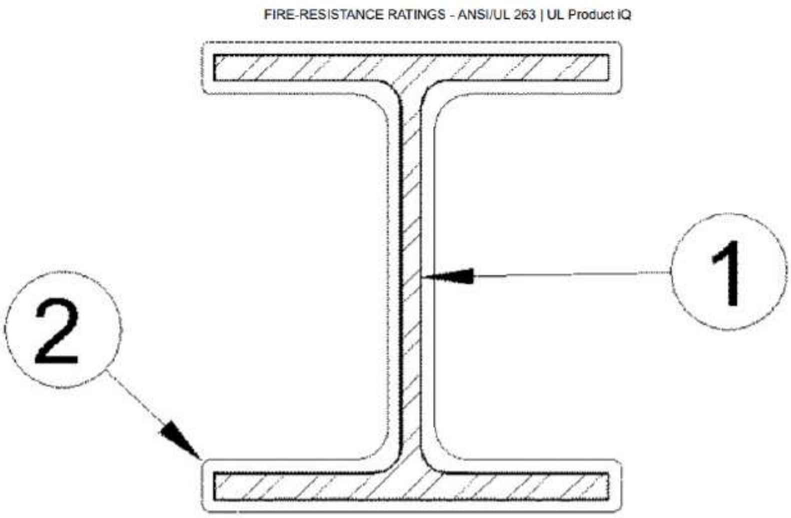
Ro=172 min.

Intumescent Coatings:

Intumescent coatings are thin chemical films that include a mixture of binders, resins, ceramics and refractory fillers. These films expand under high temperatures and form a durable, adherent, fire resisting cellular foam layer as gases within the film attempt to escape. Coating thickness can range from1/ 8 in. to 5/8 in. and fire resistance ratings up to 3 hours are possible.

A minimum column size is always specified for each test. Only columns of the same configuration with the same or larger W/D (or A/P) ratios and the same thickness of coating as that tested can be used. For example, if the test report indicated a minimum W10x49 (W/D = 0.840) column section, the test would be an appropriate reference for a W8x40 (W/D = 0.849) column section.

UL X649 Method:



Fig#8: Column with intumescent coating.

1. Steel Column — Wide flange steel columns with the minimum sizes shown in the tables below. Columns shall be free of dirt, loose scale and oil. Columns shall be primed with a phenolic modified alkyd resin primer, a metal alkyd primer, an acrylic primer or an epoxy primer at a nominal thickness of 2 mil.
2. 2. Mastic and Intumescent Coatings* — Coating spray, brush or trowel applied directly from containers to desired thickness (see Fig#8). See Tables#10 below for appropriate final dry thickness and applicable rating.

Table#10: Dry thickness and fire rating for fire rated intumescent coating.

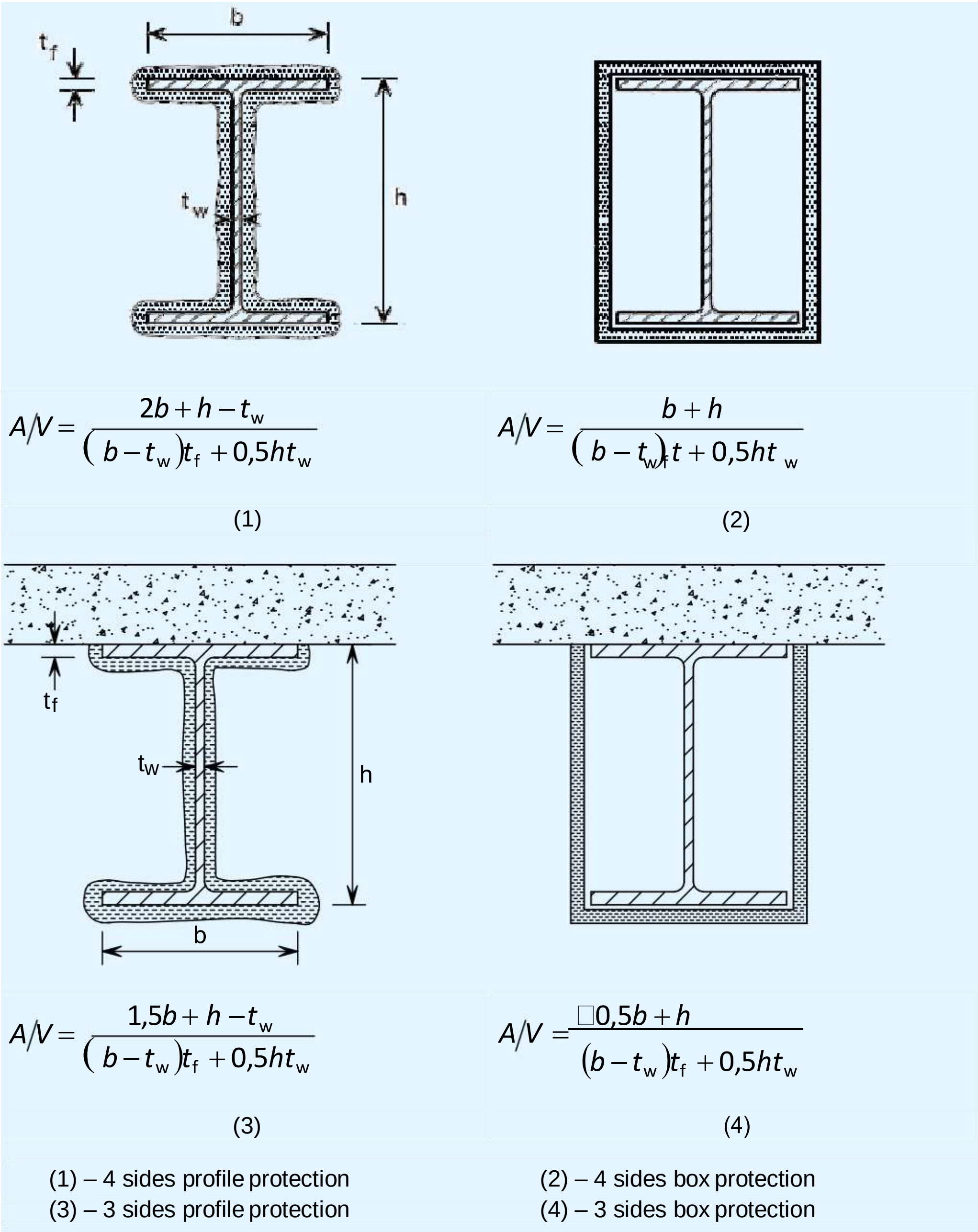
Steel Size	W/D	1 Hr Min Thickness, In.	1-1/2 Hr Min Thickness, In.	2 Hr Min Thickness, In.	3 Hr Min Thickness, In.	4 Hr Min Thickness, In.
W8 x 10	0.33	0.145	0.266	NR	NR	NR
W12 x 14	0.36	0.133	0.263	NR	NR	NR
W12 x 16	0.41	0.117	0.230	NR	NR	NR
W6 x 12	0.44	0.109	0.215	0.338	NR	NR
W8 x 15	0.48	0.100	0.197	0.310	NR	NR
W10 x 22	0.52	0.092	0.182	0.286	NR	NR
W4 x 13	0.55	0.087	0.172	0.271	NR	NR
W6 X 16	0.58	0.083	0.163	0.257	0.504	NR
W8 x 24	0.59	0.075	0.130	0.213	0.504	NR
W14 x 34	0.63	0.075	0.130	0.213	0.489	NR
W8 x 28	0.68	0.070	0.130	0.213	0.453	NR
W8 x 35	0.74	0.065	0.128	0.201	0.416	NR
W10 x 39	0.78	0.061	0.121	0.191	0.395	NR
W10 x 49	0.84	0.057	0.113	0.177	0.367	NR
W10 x 45	0.89	0.054	0.106	0.167	0.346	NR

The Prescriptive Method by EUROCODE:

Like the W/D ratio, Euro code use section factor to determine the fire resistance time. For a given product, the thickness of fire protection depends on the required fire resistance and on the section factor of the steel members. The section factor varies with the choice of fire protection and with the type and size of steel member. The critical temperature and the section factor calculation, based on the configuration of fire protection and the geometric properties of the steel section by euro code, shown in below Table#11 and Fig#9.

Table11: Critical Temperatures based on EUROCODE.

Category	Exposure	Allowable temperature (*C)			Allowable temperature (*C)		
		Load ratio			Load ratio		
		0.55	0.6	0.65	0.55	0.6	0.65
Office, Residence School, Hospital etc.	3 sided	635	620	605			
	4 sided	570	555	540	560	540	525
Storage building	3 sided	635	620	605			
	4 sided	570	555	540	560	540	525



Fig#9: Protection configuration and section factor

The required fire resistance period is determined by the national building regulations in each country. Based on datasheets of the manufacturers, the thickness of protection materials can be easily defined.

Datasheets are usually published by manufacturers. In some countries manufacturers' datasheets have been consolidated into reference documents published by the relevant body and agreed move by the designers.

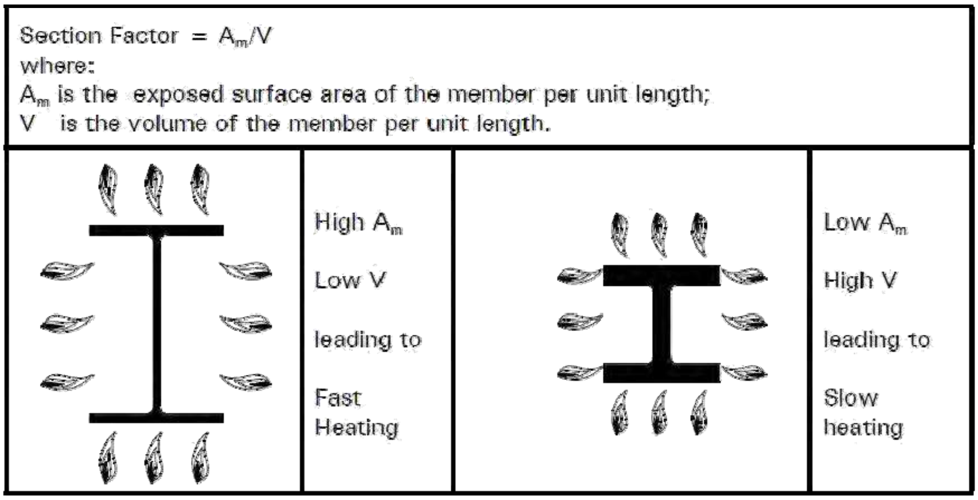
Section factor A_m/V

An important parameter in the rate at which the temperature of a member increases is the ratio A_m/V of the member, commonly known as the section factor. The section factor is defined as the ratio of the exposed surface area of a member to its volume per unit length.

Based on the section factor, fire protection materials thickness is determined for protected and unprotected. A larger section factor leads to a faster heating of the member. For example, after 15 minutes of fire exposure, the temperature of an unprotected member with a section factor of A_m/V = 200 increases to about 580^{0}C, while that of the unprotected member with A_m/V = 100 only reaches 380^{0}C.

This difference is due to the fact that a large value of the section factor represents a large exposed surface area compared with its volume, and therefore, the member receives more heat than that with a low section factor, which represents a small exposed surface area.

This is illustrated in Fig#10.

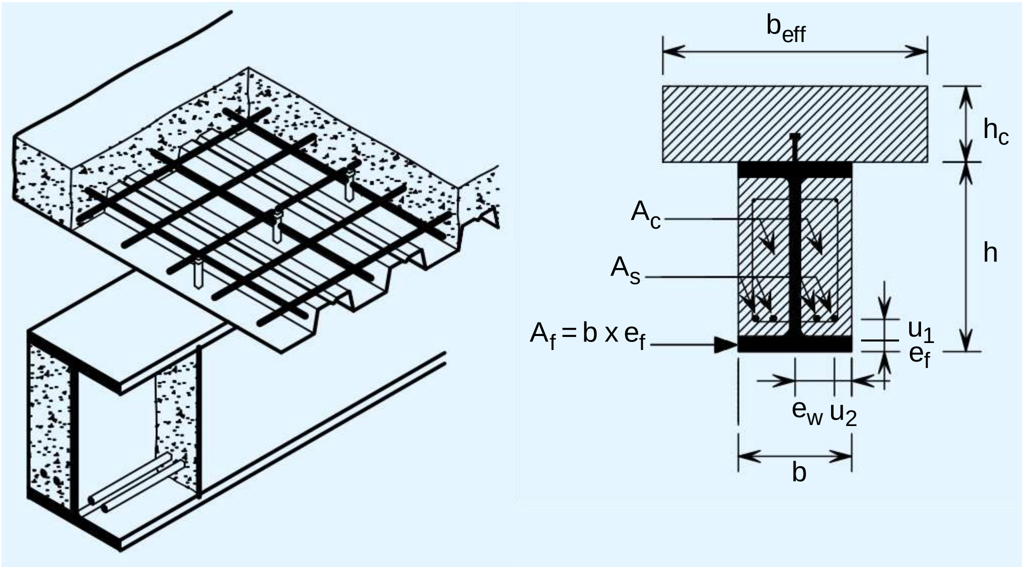


Fig#10: Definition of section factor A_m/V of a member in fire

2.5 Partially Encased Beams and Columns

Partially encased beams and columns are constructed by filling the space between the flanges of I-sections using plain or reinforced concrete, as shown in Fig#11 and Fig#12.

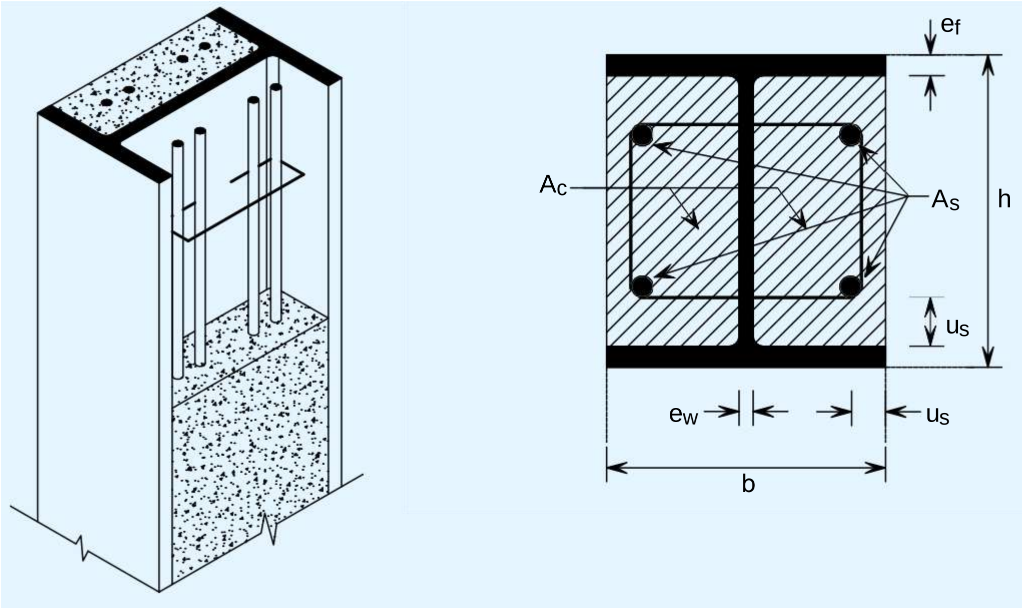
Compared with the unprotected I-sections, which only have about 15 minutes fire resistance, partially encased sections can achieve over 60 minutes, which normally meets the fire resistance requirements of many multi-stored buildings. The increase in fire resistance period is due to the coverage of most parts of the surface area of the steelwork using concrete, which has a low thermal conductivity. Longer periods of fire resistance can also be achieved by increasing the amount of reinforcement embedded within the concrete, to compensate the loss of the strength of the steelwork in fire.



Fig#11: Partially Encased Beam

EN 1994-1-2 offers relatively simple rules and established datasheets in Clauses §4.2.2 and §4.2.3 for fire design of composite beams and columns, including partially encased steel sections. These rules relate the fire resistance of composite members to their load level (the load level is denoted as $\eta fi,t$ and is described in Sections 4.4.2 and 4.4.3 of this guide), the *h*/*b* ratio, the member type and the area of reinforcement A_s.

Generally, an increase of the fire resistance or the load level requires larger cross-sections and additional reinforcement for partially encased sections. The datasheets can be used to determine the minimum cross-sectional dimensions (such as the section width b_{min}) and reinforcement ratio $A_{s,min}$ of partially encased sections, to achieve the required fire resistance period.



Fig#12: Partially Encased Column.

Table12. show a datasheet taken from EN 1994-1-2 for the fire design of partially encased sections. When using this type of design data, the load level $\eta_{fi,t}$ may be calculated as follows:

$R_{fi,,d,,t} = \eta_{fi,t} \cdot R_d$

where:

$R_{fi,d,t}$ is the design resistance of the member in fire conditions at time, t.

R_d is the design resistance of the member for room temperature design.

When calculating the load level, EN 1994-1-2 recommends that the design resistance for room temperature design, R_d, is calculated for a buckling length that is twice the buckling length used for fire design.

Table 12: Typical datasheets for fire design of partially encased sections

Member	Section Ratio *h/b*	Load level	Width b_{min}(mm)/Reinforcement $A_{s,min}$ ratio (%) for the required fire resistance period (min)				
			R30	R60	R90	R120	R180
Beam	>1,5	$\eta_{fi,t} \leq 0,5$	80/0,0	150/0,0	200/0,2	240/0,3	300/0,5
		$\eta_{fi,t} \leq 0,7$	80/0,0	240/0,3	270/0,4	300/0,6	
	>3,0	$\eta_{fi,t} \leq 0,5$	60/0,0	100/0,0	170/0,2	200/0,3	250/0,3
		$\eta_{fi,t} \leq 0,7$	70/0,0	170/0,2	190/0,4	270/0,5	300/0,8
Column	Minimum *h* and *b*	$\eta_{fi,t} \leq 0,47$	160/-	300/4,0	400/4,0		
		$\eta_{fi,t} \leq 0,66$	160/1,0	400/4,0			

As an example, consider the case of a partially-encased beam with a ratio $h/b > 3$, under moderate load ($\eta_{fi,t} \leq 0,5$).

For a fire resistance period of 60 minutes (R60):

- The width should not be less than 100 mm, which leads to $h > 3b = 300$ mm. So the minimum cross-sectional area is 100 × 300 mm
- No reinforcement is required, $A_s = 0$.

To achieve a fire resistance period of 120 minutes (R120):

- The width should not be less than 200 mm. Therefore the height $h > 3b = 600$ mm and therefore the minimum cross-sectional area is 200 × 600 mm
- The reinforcement area, A_s, should not be less than 0,3% of the encased concrete area A_c, *i.e.*, $A_s \geq 0{,}003A_c$.

To achieve a fire resistance period of 180 minutes (R180):

- The width should not be less than 250 mm. Therefore the height $h > 3b = 750$ mm and therefore the minimum cross-sectional area is 250 × 750 mm
- The reinforcement area, A_s, should not be less than 0, 3% of the encased concrete area A_c, *i.e.*, $A_s \geq 0{,}003A_c$.

SFRM System based on A/Vm: MPB building's beam fire protection calculation by Isolatek CP2 is shown in Table 13.

Table 13: Beam fire protections are provided by Isolatek CP2.

Client : NULLIFIRE BANGLADESH
Project : Bangladesh Project
Fire Rating : 180 Minutes
Material : Isolatek CP2

									3 Hrs	
									CP-2-BS	
No	Member	Type	Material Section	Web	Flange 1	Flange 2	Hp/A	W/D	Design	Thickness
1	Beam	Beam no-3	PG 600x300x200x160kg/m	600	200	300	96	1.396		39
2	Beam	Beam no-4	PG 600x300x200x143kg/m	600	200	300	106	1.264		41
3	Beam	Beam no-5	PG 600x250x200x135kg/m	600	200	250	110	1.218		42
4	Beam	Beam no-6	PG 600x150x150x117kg/m	600	150	150	114	1.175		43
5	Beam	Beam no-7	PG 300x300x300x96kg/m	300	300	300	126	1.063		44
6	Beam	Beam no-8	PG 600x210x150x82kg/m	600	150	210	167	0.802		49
7	Beam	Beam no-9	PG 600x210x150x80kg/m	600	150	210	171	0.784		49
8	Beam	Beam no-10	PG 600x200x150x79kg/m	600	150	200	172	0.779		49
9	Beam	Beam no-11	PG 600x200x140x75kg/m	600	140	200	179	0.749		49
10	Beam	Beam no-12	PG 400x200x200x71kg/m	450	200	200	169	0.793		49
49	Beam	Beam no-13	PG 450x200x140x63kg/m	450	140	200	176	0.761		49
12	Beam	Beam no-14	PG 300x250x150x59kg/m	300	150	250	157	0.853		48
14	Beam	Beam -1	PG 600x300x200x226kg/m	600	200	300	68	1.970		34
15	Beam	Beam -2	PG 600x300x200x177kg/m	600	200	300	87	1.540		38

Section Summary - Structure Design & Construction Materials.

In most of the countries in the world, the IBC is used as their prefered fire code for structural fire protection. However, in Bangladesh, fire resistive requirements for structural components are selected based on Bangladesh National Building Code which is the toughest code. So, even if I have discussed the NFPA and IBC, required structural fire protections are completed by BNBC based on Type-1 construction.

Due to MPB's Type- IA construction and separation distance, the building's structural elements were required to meet a minimum fire resistance rating. The MPB's number of stories, floor area and construction type are all within the requirements prescribed in the IBC.

In an effort to protect this structure, a fire detection/ alarm and communication system was installed throughout the facility.

Fire Detection Systems

3.1 Fire Detection, Alarm and Communication Systems

Fire Detection system is an active life safety system for any building occupancy. Life safety systems aren't installed just as precautionary measures; either building codes dictate that every business must contain a functioning fire system to remain operational.

Fire alarm system equipment within the building includes:

- A Fire Alarm Control Panel
- NAC extended Power supply.
- Manual pull stations
- Photoelectric smoke detectors placed in locations specified by NFPA 72
- Fire alarm input/output device
- Horn/strobe units and strobes for audible and visual occupant notification
- Fire sprinkler system water flow switches
- Valve tamper switches

The warehouse and mixed occupancy fire alarm system is classified as a Protected Premise Fire Alarm System that also serves as a Building Fire Alarm System in accordance with NFPA 72. As such, the fire alarm system serves the general fire protection needs of the building; provides for automatic fire department notification and initiation of emergency response organizations in the event of fire; and provides for occupant notification, supervisory and trouble signals to a Remote Supervisory Station serving the construction site and surrounding areas.

The primary objective of the fire detection, alarm and communication systems installed at the BPB building is to protect occupants. To achieve this goal, a prescriptive-based design approach was utilized. Listed components were installed in compliance with applicable provisions of *NFPA 70, National Electrical Code, NFPA 72, National Fire Alarm Code*, as well as, additional recognized standards, local codes and ordinances.

The system was designed to be an "intelligent" fire alarm control system capable of communicating with devices and performing process management tasks such as unlocking doors, recalling elevators, etc. The system was also designed to provide emergency voice/alarm communications and to be continuously monitored by an off premise monitoring company.

3.2 Initiating Devices

The term initiating device refers to all forms of signal input sensors and devices, such as smoke detectors, pull stations, sprinkler alarm valve in zone control etc., that supply an incoming signal to the fire alarm control unit (FACU). These devices respond to environmental changes produced by a fire called “fire signatures”. Heat, smoke (aerosol particulates) and radiant energy (IR, UV or visible) are among the most frequently used fire signatures for the basis of detection.

NFPA 72 Chapter 17 Section 17.6.3.1.1 requires that option one or two are met (1) *The distance between detectors shall not exceed their listed spacing, and there shall be detectors within a distance of one half the listed spacing, measured at right angles from all walls or partitions extending upward to within the 15 percent of the ceiling height.* (2) *All points on the ceiling shall have a detector within a distance equal to or less than 0.7 times the listed spacing (0.7S)*

The Photoelectric or ionization smoke sensor (smoke detector) is installed in compliance with NFPA 72. Ground has three smoke detectors installed in electrical room and two elevator lobbies. Apart from ground floor, two smoke detectors installed in two lobbies on each floor.

All signaling line circuits are wired in conformance with Class A standards. One advantage of Class A circuits is any detector’s malfunction will not affect other devices on the circuit. One disadvantage of Class A circuits is that four wires are required in Class A circuit (see Fig#13,13A).

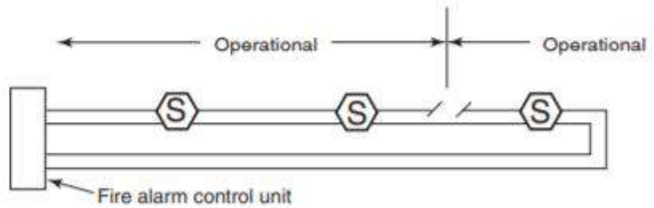


FIGURE F.2.4 Circuit-Powered (Two-Wire) Smoke Detectors for Class A Initiating Device Circuits.

Figure 13. Illustration of Class A Circuit in SLC Circuit.

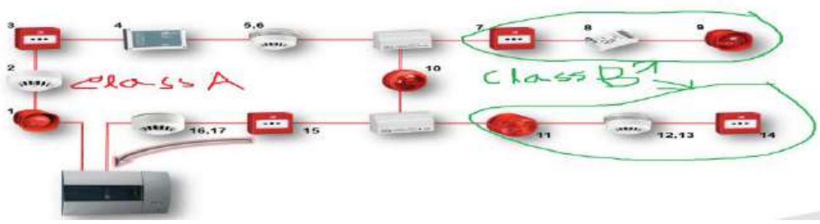


Fig13A: Difference between Class A and Class B Circuit.

3.3 Sprinkler

Sprinklers acting as heat detectors are the most numerous style of initiating device found in the BPB building. This is largely due to the fire water suppression system installed in the building. Sprinkler heads are a portion of the fire water suppression system intended to sense heat produced by a fire and react by discharging water to the fire area. The majority of sprinkler heads at BPB building is produced by TYCO and is expected to activate at 155-160°F. These sprinkler heads are considered initiating devices because once water begins to flow through a sprinkler head, a flow switch from the zone control valve near the each sprinkler riser initiates an alarm sequence at the FACU on each floor. To have a quick alarm signal, three zone control valves are provided on each floor and the flow switch is set on zero retard time (see Fig#14,14A,14B)

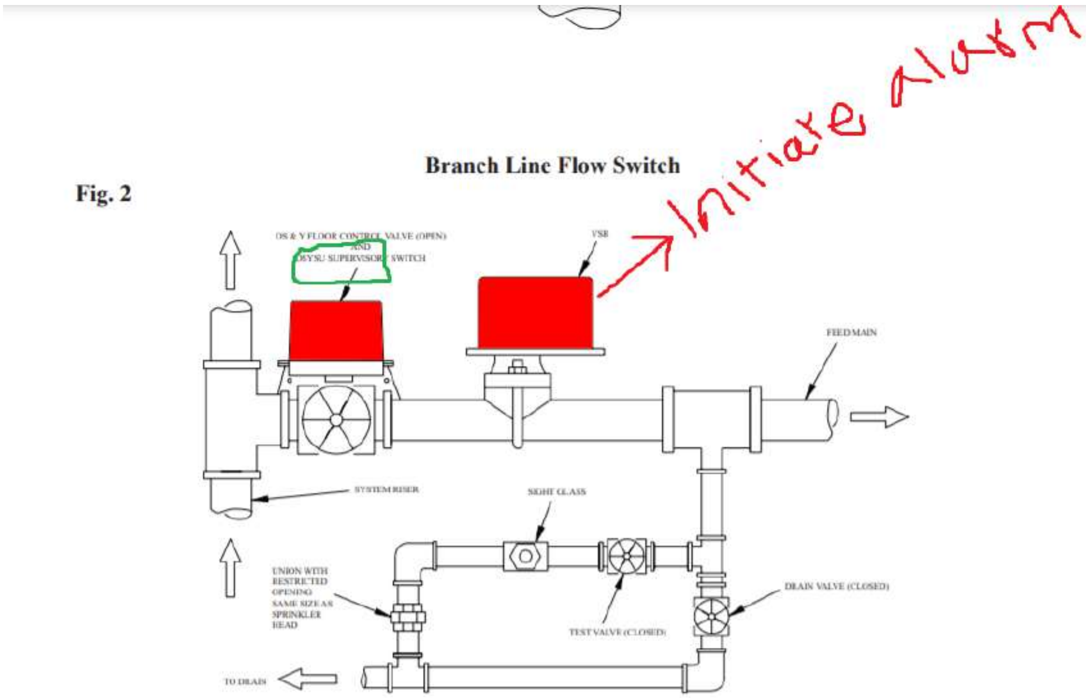


Fig14: Sprinkle Floor Control Assembly.

Fig14A: Water Flow Alarm Switch.

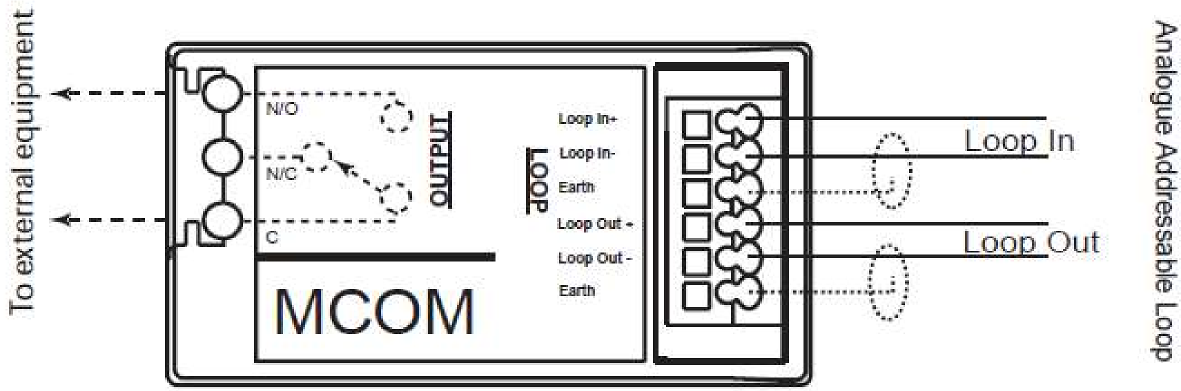


Fig14B: Cooper Monitor Module for Alarm Valve.

Smoke Detectors

In most applications, smoke detectors are expected to detect a fire significantly faster than heat detectors. Cooper spot-type photoelectric smoke detectors are installed in the two elevator lobbies on each floor, one smoke detector in the electric room on the ground floor, one smoke detector on each lift machine room. These devices have a listed spacing of 30 feet and are installed at the facility on the ceiling or on a sidewall within 12 inches of the ceiling. These devices are all intelligent (i.e. addressable, Class, Fig#15) and utilize the light scattering principal to detect smoke.

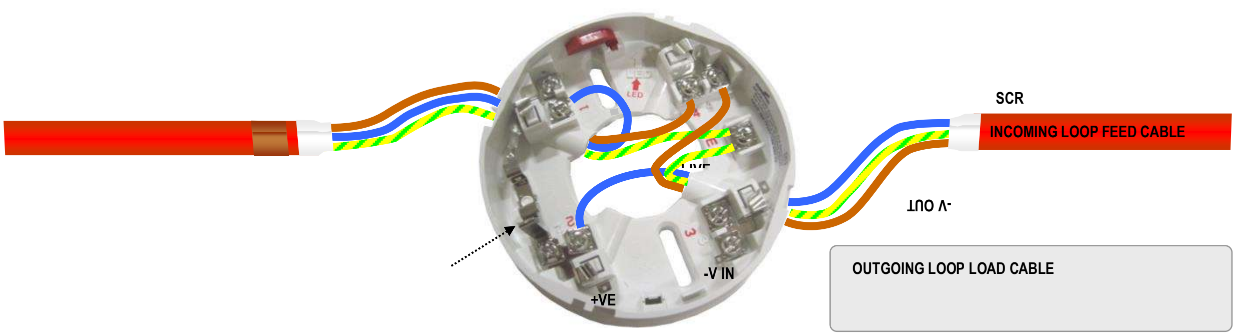


Fig15: Class A Circuit of Smoke Detector.

3.4 Pull Stations

Manually activated alarm-initiating devices, commonly referred to as “pull stations”, were installed in MPB building to allow building occupants to manually initiate the fire signaling system. Double action Cooper addressable pull stations can be found within 5 feet of each exit doorway, as well as, in close proximity to the entry of all stairways. The devices are securely mounted between 3.5 – 4 feet above the finished floor.

All devices are red in color and clearly identifiable from a distance. Access to these locations is free and unobstructed. As occupants evacuate the BPB building, they should be able to easily locate and, if warranted, activate these devices (see Fig#16 & 16A).

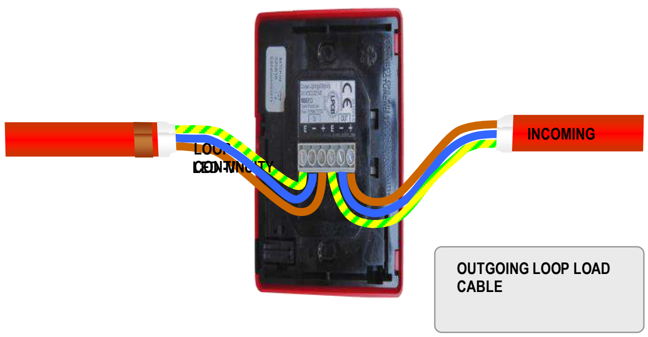


Fig16: Circuit Diagram of MCP Class A Circuit.

Fig16A: Manual Pulls Station.

3.5 Fire Alarm Control Panel (FACP):

At the heart of any fire alarm or mass notification system is the head-end, or the brain. Modern systems use a central processing unit (CPU) housed in what is referred to as a fire alarm control unit (FACU) in NFPA 72. The FACU is a specialized panel that provides system status, system control, and battery backup and receives signals from initiation devices and then outputs signals to notification and auxiliary devices (see Fig#17).

A small building is likely to have one FACU, to which all devices connect. A large building or campus will have many FACUs, extender panels, or expansion panels. Expansion panels, sometimes called transponder panels, do not contain the CPU but offer the same connectivity as a FACU. Large systems require connectivity between panels to facilitate communication of alarm events and status.

It is important for communication to be maintained at all times, so a loop-based topology is important to strive for. The benefit of a communication loop is that a wiring failure (due to physical damage of wiring) can be identified without loss of communication. This reliability is especially important for voice notification and mass notification systems.

Eaton's CF3000 is a high specification intelligent addressable control panel which is available in various loop configurations. These panels combine sophisticated functionality with simple operation and an aesthetically pleasing design.
The large capacity, ability to support complex cause and effect programming and wide range of user controllable functions make the system suitable for a diverse range of projects from sheltered housing to large office developments. The CF3000 uses soft addressing to minimize installation time and remove the potential for error associated with manual addressing. It can operate as a stand-alone panel or as part of a networked system. They have powerful programming options that allow configurable control over whether messages from specific panels are transmitted around the network or remain local. An extensive range of compatible intelligent addressable systems ancillaries are available to work with the CF3000 all of which incorporate an integral short circuit isolator to provide maxim

Fig#17: Cooper fire alarm Panel.

For example, if the FACP receives an alarm signal from a manual pull station, the FACP initiates the following responses:

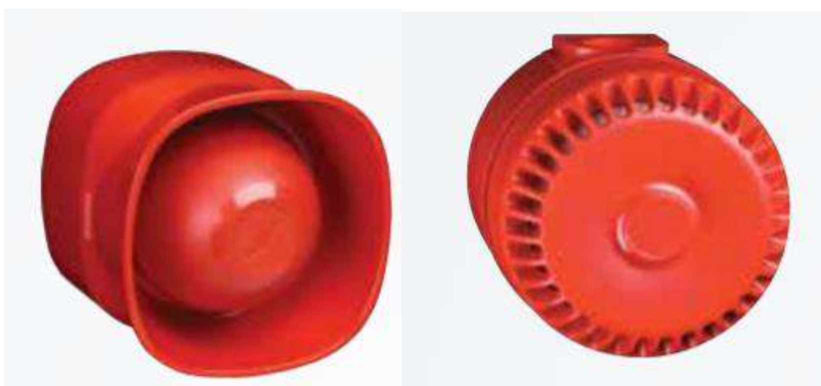
- Actuate Common Alarm Signal;
- Actuate Audible Alarm Signal;
- Actuate General Alarm Indicator;
- Actuate Building Evacuation Signals o throughout the building;
- Display/ Print Change of Status;
- Transmit Fire Alarm Signal to Supervising Station;
- Release Magnetically Held Smoke Doors;
- Unlock Exits; and,
- Annunciate at Remote Annunciator.

The design and installation of the FACP was not identified to violate the intent of any pertinent building codes and fire safety standards. Cooper Audible sounders (FX -horn) with 110 dB are installed throughout storage occupancy of 3rd, 4th and 5th floors. Cooper HSR Horn- Strobes are installed throughout the factory/industry occupancy of Ground, 1st & 2nd floors due to higher ambient sound.

2.3.1 Notification Devices

A fire alarm notification appliance is an active fire protection component of a fire alarm system. A notification appliance may use audible, visible, or other stimuli to alert the occupants of a fire or other emergency condition requiring action (see Fig#18 & 18A).

The FACU processes signals received from initiating devices and responds appropriately. In many cases, this response will include the activation of notification devices. Notification devices are intended to alert occupants of a potential emergency situation, convey pertinent information and encourage occupants to initiate appropriate response actions. Audible and visible notification devices were installed in the MPB building. See Appendix 2 for notification device location details. All notification appliance circuits are wired in conformance with Class “B” Style “Y” standards. This general purpose surface FX sounder has been specifically designed to work with intelligent addressable sounder. Volume is adjustable via the internal volume control and 32 different alarm tone selections are provided. Depending on the selected tone, sound levels of up to 110dB (A) can be achieved.



Fig#18: Cooper FX Horn, wall mounted.

The HSR-Horn Strobe range of notification devices are designed to exceed your expectations and offer the most polished, feature rich and cost effective solution.

•80% reduction in SKUs - Up to 9 models now in 1 appliance.
• 3 audible settings.
•8 candela settings in 1 device Wall - 15/1575/30/75/95/110/135/185 Ceiling - 15/30/60/75/95/115/150/177.

Fig#18A: Cooper HSR-Horn strobe, wall mounted.

No code violations or deficiencies related to the design or installation of notification devices were identified. Voltage drop calculation has been provided for notification devices in Table 14.

Table 14: Voltage drop Calculation. Voltage=24 VDC, Wire size = 12 AWG, Vter =20.4vdc.

NAC CKT no	Strobe cd (number)	Horn (110dB)	resistance Ω/1000ft	Length (ft)	Total AMP	Voltage drop (dc)	Vload> 16 Vdc	Satisfied
FACP NAC-1		39	1.61	2000	0.624	2.00	18.4	Yes
NAC EXT-1	185cd (12) 110cd (4)		1.61	640	3.94	4.05	16.34	Yes
NAC EXT--2	185cd (12) 110cd(4)		1.61	680	3.94	4.31	16.08	Yes
NAC EXT-3	185cd (12) 110cd(3)		1.61	720	3.75	4.35	16.04	Yes
NAC EXT-4	185cd(0) 110cd (16)		1.61	760	2.94	3.60	16.79	Yes

Audible Notification:

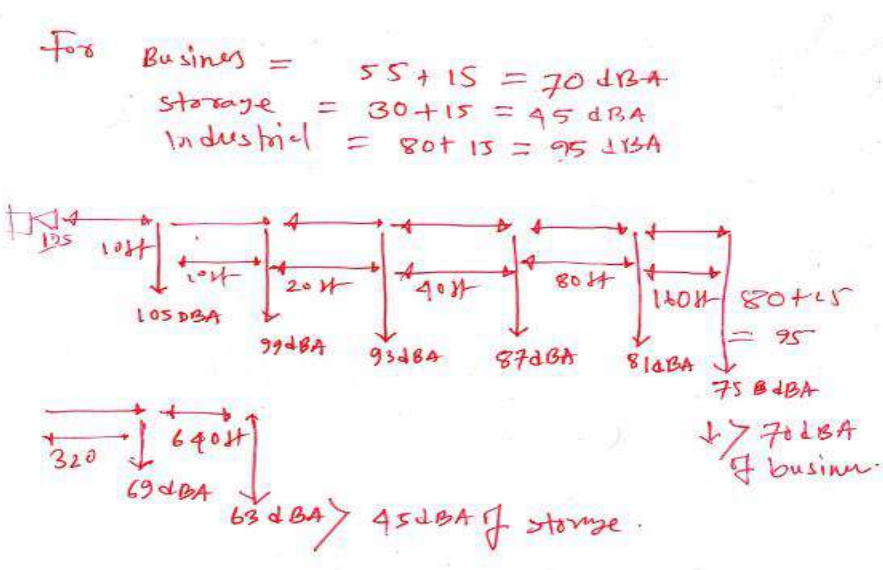
Audible notification appliances operating in public mode are not required to produce a minimum sound pressure level (SPL). However, these devices are required to produce a SPL at least 15 dB above the average ambient sound level (NFPA 72 18.4.3.1). For business occupancies, the average ambient sound level is anticipated to be approximately 55 dBA and storage occupancy of 30 dBA (See Table 15). As a result, a SPL of 70 dBA is required throughout business occupancy of the BPB Building and at least 45 dBA for storage occupancy (See Fig#19). For Factory occupancy, the average ambient sound level is anticipated to be approximately 80 dBA. So, at least 95 dBA is required to be provided. That is why visual notification (strobe) are provided on the Ground, 1st and 2nd floors of the building. To ensure signals were clearly broadcasted from these devices, each device was set at a specific sound output level based on the device's environment and relative location to other audible notification devices.

The sound output of these devices can be adjusted by modifying the device's wattage setting. Most devices installed throughout MPB are set to sound pressure of 105 dBA.

Table 15: Average Ambient Sound Level (dBA).

Δ **Table A.18.4.4 Average Ambient Sound Level According to Location**

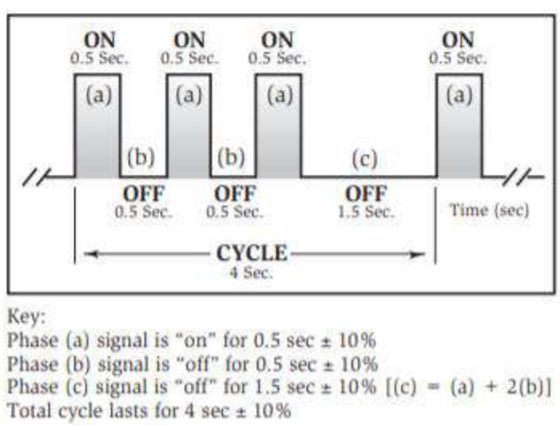
Location	Average Ambient Sound Level (dBA)
Business occupancies	54
Educational occupancies	45
Industrial occupancies	88
Institutional occupancies	50
Mercantile occupancies	40
Mechanical rooms	91
Piers and water-surrounded structures	40
Places of assembly	60
Residential occupancies	35
Storage occupancies	30
Thoroughfares, high-density urban	70
Thoroughfares, medium-density urban	55
Thoroughfares, rural and suburban	40
Tower occupancies	35
Underground structures and windowless buildings	40
Vehicles and vessels	50



Fig#19: Calculation of dBA Based on Ambient Sound to NFPA.

A horn/strobe device was also installed on the outside of BPB building near the fire pump room to assist arriving response personnel in locating this area.

Another important audibility requirement to be adopted by the NFPA is the Temporal Code (see Fig#20). This code was developed to establish a universal evacuation signal to lessen confusion as to whether an alarm represents an emergency requiring complete evacuation of the building.

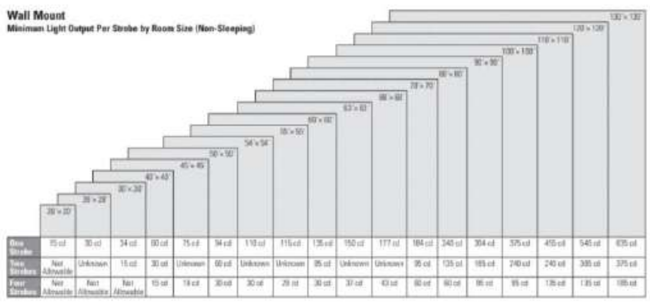


Fig#20: Temporal Three Code

Visual Notification:

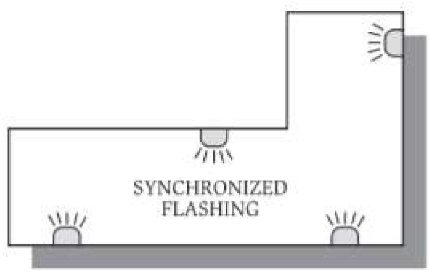
The visual feature (strobe) of the notification devices can also be adjusted to provide a range of candela (cd) intensities. The visual notification devices installed in BPB Building have standard field selectable candela settings of 110 and 185. The higher the cd setting, the larger room size one device can adequately cover (see Table 16).

Table 16. Portion of Room Spacing Table for Wall- Mounted Visible Appliances (NFPA 72)

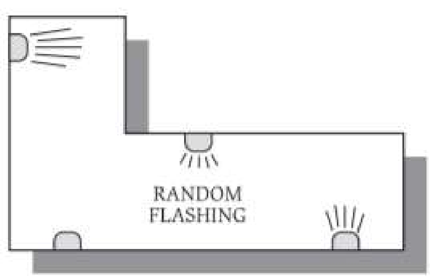


Wall Mount
Minimum Light Output Per Strobe by Room Size (Non-Sleeping)

	20' x 20'	28' x 28'	30' x 30'	40' x 40'	45' x 45'	50' x 50'	54' x 54'	55' x 55'	60' x 60'	63' x 63'	68' x 68'	70' x 70'	80' x 80'	90' x 90'	100' x 100'	110' x 110'	120' x 120'	130' x 130'
One Strobe	15 cd	30 cd	34 cd	60 cd	75 cd	94 cd	110 cd	115 cd	135 cd	150 cd	177 cd	184 cd	240 cd	304 cd	375 cd	455 cd	540 cd	635 cd
Two Strobes	Not Allowable	Unknown	15 cd	30 cd	Unknown	60 cd	Unknown	Unknown	95 cd	Unknown	Unknown	95 cd	135 cd	185 cd	240 cd	240 cd	305 cd	375 cd
Four Strobes	Not Allowable	Not Allowable	Not Allowable	15 cd	19 cd	30 cd	30 cd	28 cd	30 cd	37 cd	43 cd	60 cd	60 cd	95 cd	95 cd	135 cd	135 cd	185 cd



Fig#21: Acceptable to NFPA72.



Fig#21A: Not acceptable to NFPA 72.

When determining where to place these devices, efforts were made to place them in the anticipated viewing path of the target audience (See Fig#21 & 21A). Wall-mounted devices were usually installed on the wall that the majority of occupants are expected to face.

The appliance itself is not required to be visible from any location in a space. If the device is not visible, the operating effects (illumination of the surrounding area) must be able to be seen by the intended viewers (NFPA 72 18.5.1).

3.6 Emergency Communication Systems (ECS)

The emergency public address system is required throughout the facility in accordance with NFPA 72. The system may be used for general public address. Public address system shall be provided for an emergency audio distribution network, and shall include microphones, compact disk player, AM (and FM) radio tuner, (MD player) amplifiers, control for each input, output selector switches, wiring, loudspeaker, and all necessary accessories required to control and reproduce audio signals from any input source to any output location. In addition to sounding an alarm tone, the audible notification speakers can be used to transmit specific communications for different emergencies (hurricane, tornado, hazmat incident, etc.). Authorized MPB personnel can use the FACU to initiate pre-recorded voice messages or use the microphone to provide live instructions. While assessing MPB's ECS, it was identified that posted instructions for how to use the microphone for live voice announcements had not been provided as required by NFPA 72 24.3.2.

3.7 Intelligibility

NFPA has specific requirements for speech intelligibility, which may be measured as speech transmission index, rapid speech transmission index, speech intelligibility index, articulation index, or common intelligibility scale. These systems provide a single number score, with higher scores indicating higher intelligibility performance. To ensure messages are intelligible, audible notification devices with high fidelity speakers and low distortion were selected.

Intelligibility could be increased in areas with lower ceilings by decreasing the space between speakers. This would ensure that the intended listener is always located in a direct field of a single speaker. Message intelligibility usually decreases if a person is in the direct field of more than one speaker.

Voice evacuation:

Horns and strobes can alert employees to immediate fire dangers, but the frequent occurrence of fire drills and false alarms can create "alarm fatigue," dulling the sense of urgency typically associated with such events. Additionally, simply blaring alarms through a large facility can lead to a chaotic evacuation. Voice evacuation systems were created to alleviate these problems. As an enhancement of a traditional fire alarm system, a voice evacuation system broadcasts pre-recorded messages throughout a building to guide occupants out of the building through the safest route using coherent direction. The systems are extremely versatile, as recordings can be made for various life safety situations, including fires, severe weather, gas leaks, active shooters, and more.

A more organized evacuation procedure can equate to less risk to a building's occupants, and the ability to record customized messages for different emergency scenarios gives a voice evacuation system a distinct edge over the standard "same alarm for every situation" horns and strobes solution. Voice evacuation systems work so well that Bangladesh requires them in high-occupancy assembly, educational, and high-rise facilities. Some industry experts believe voice evacuation systems will eventually completely replace standard horn/strobe systems as technology becomes streamlined and code compliance changes.

3.8 Two-way Communication Systems

A two-way in-building ECS was installed in BPB to ensure there was a reliable way for emergency response personnel to communicate during an emergency. Multiple emergency telephone handsets or "fire fighters' telephones" are provided near the FACP. These are often provided because a firefighter's handheld radio may be ineffective in a building with a large amount of steel or when there is a great deal of radio traffic. Telephone jacks are provided on all floors outside elevator entrances.

3.9 Secondary Power Supply

According to NFPA 72, a secondary power supply is required for the fire alarm system that has "sufficient capacity to operate the system under quiescent load for a minimum of 24 hours and, at the end of that period, shall be capable of operating all notification appliances for 5 minutes (10.6.7.2.1)." A minimum safety margin of 20 percent above the calculated amp-hour capacity is also required.

Secondary power for the FACP and all the initiation devices is provided via two 12-volt 26 amp-hour batteries wired in series located in the FACP. The required battery capacity was calculated to be 6 amp-hours (see Table 17). In conclusion, adequate secondary power is provided for these devices.

Table 17. Battery Calculations for the FACP and All Initiating Devices

Fire Alarm System Secondary Battery-set Calculation Worksheet

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL ALARM CURRENT PER ITEM
FACU	Fire Alarm Control Unit	0.1700	X	1	=	0.1700	0.2000	X	1	=	0.2000
SD	Smoke Detector	0.0002	X	11	=	0.0022	0.0500	X	11	=	0.5500
M	I/O module	0.0003	X	62	=	0.0198	0.0200	X	62	=	1.2400
RLY	Relay (failsafe)	0.0500	X	0	=	0.0000	0.0000	X	0	=	0.0000
RLY	Relay (not failsafe)	0.0000	X	0	=	0.0000	0.0500	X	0	=	0.0000
FX	Horn (110dB)	0.0000	X	72	=	0.0000	0.0160	X	72	=	1.1520
DH	Door Holder	0.0650	X	0	=	0.0000	0.0000	X	0	=	0.0000
ANN	Annunciator	0.1000	X	0	=	0.0000	0.2000	X	0	=	0.0000
MS	Manual Station	0.0004	X	36	=	0.0133	0.0200	X	36	=	0.7200
WF	Waterflow Switch	0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
TS	Tamper Switch	0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
0	0	0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
0	0	0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
					TOTAL SYSTEM STANDBY CURRENT (AMPS)	0.2054				TOTAL SYSTEM ALARM CURRENT (AMPS)	3.8620
Prepared for:		REQUIRED STANDBY TIME (HRS) NFPA 72-2002 4.4.1.5.3.1		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) NFPA 72-2002 4.4.1.5.3.1		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
		24	X	0.2054	=	4.9286	0.083	X	3.8620	=	0.3205
Prepared by:		REQUIRED STANDBY CAPACITY (AMP-HOURS)		REQUIRED ALARM CAPACITY (AMP-HOURS)		TOTAL CAPACITY (AMP-HOURS)	TOTAL CAPACITY (AMP-HOURS)		SAFETY FACTOR		ADJUSTED BATTERY CAPACITY (AMP-HOURS)
		4.93	+	0.3205	=	5.2492	5.2492	X	120%	=	6

One Remote Power Supply Cabinets provide secondary power for groups of notification devices. These cabinets contain two 12 volt 7 amp-hour batteries wired in series. The cabinet with the largest power draw (Remote Power Supply 1A) was calculated to require 2 amp-hours (see Table 18). In conclusion, adequate secondary power is provided for these devices.

Table 18. Battery Calculations for Remote Power Supply 1A

Fire Alarm System Secondary Battery-set Calculation Worksheet

ITEM	DESCRIPTION	STANDBY CURRENT PER UNIT (AMPS)		QTY		TOTAL STANDBY CURRENT PER ITEM	ALARM CURRENT PER UNIT (AMPS)		QTY		TOTAL ALARM CURRENT PER ITEM
NEU	NAC EXTENDER UNIT	0.0310	X	1	=	0.0310	0.1410	X	1	=	0.1410
HS	Horn-Strobe(185cd)	0.0000	X	36	=	0.0000	0.2670	X	36	=	9.6120
HS	Horn-Strobe(110cd)	0.0000	X	27	=	0.0000	0.1840	X	27	=	4.9680
		0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
		0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
		0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
		0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
		0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
		0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
		0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
		0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
0	0	0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
0	0	0.0000	X	0	=	0.0000	0.0000	X	0	=	0.0000
				TOTAL SYSTEM STANDBY CURRENT (AMPS)		0.0310			TOTAL SYSTEM ALARM CURRENT (AMPS)		14.7210
Prepared for:		REQUIRED STANDBY TIME (HRS) NFPA 72-2002 4.4.1.5.3.1		TOTAL SYSTEM STANDBY CURRENT (AMPS)		REQUIRED STANDBY CAPACITY (AMP-HOURS)	REQUIRED ALARM TIME (HOURS) NFPA 72-2002 4.4.1.5.3.1		TOTAL SYSTEM ALARM CURRENT (AMPS)		REQUIRED ALARM CAPACITY (AMP-HOURS)
		24	X	0.0310	=	0.7440	0.083	X	14.7210	=	1.2218
Prepared by:		REQUIRED STANDBY CAPACITY (AMP-HOURS)		REQUIRED ALARM CAPACITY (AMP-HOURS)		TOTAL CAPACITY (AMP-HOURS)	TOTAL CAPACITY (AMP-HOURS)		SAFETY FACTOR		ADJUSTED BATTERY CAPACITY (AMP-HOURS)
		0.74	+	1.2218	=	1.9658	1.9658	X	120%	=	2

Analysis of Fire Detector Response:

In this section, a fire scenario is identified and justified. The expected response characteristics of the fire detection devices (sprinkler as fire initiating device) installed in the storage building are calculated and the fire size and the time of detector for the scenario is also calculated. The sprinkler heads in the BPB Building will activate at 155 ◦F. Based on how the fire started and how it is traveling, we will assume it copies the behavior of a fast fire. The fire grows as a fast t-squared fire with a fire growth coefficient of $\alpha = 0.047$ kW/s^2 (this is the fire growth coefficient value for a fast fire, LSC 2018). The response time for a typical sprinkler head located in the 5th floor was determined by utilizing the DETACT implementation spreadsheet as seen below in Table #19. The ceiling height input parameter represents the height above the fire. For this scenario, the ceiling height is 16 feet. The radial distance represents the horizontal distance from the fire to the sprinkler. In this case the nearest sprinkler head is about 6 feet from the fire. The ambient temperature is assumed to be 32°C and from the sprinkler cut sheet it was determined that the actuation temperature is 68°C. The specific RTI was not provided on the sprinkler cut sheet, but since it is a standard response head, an RTI of 80 (m-s)$^{1/2}$ was assigned as standard response sprinklers have a thermal element with an RTI of 80 (m-s)1/2 or more.

Table#19: DETACT.XLS-the response time of ceiling mounted fire Sprinkler/detector.

1	DETACT.XLS: Estimate of the response time of ceiling mounted fire detectors					
2						
3	INPUT PARAMETERS			CALC. PARAMETERS		
4	Ceiling height (H)	5	m	R/H	0.646	
5	Radial distance (R)	3.2	m	dT(cj)/dT(pl)	0.401	
6	Ambient temperature (To)	20	C	u(cj)/u(pl)	0.288	
7	Actuation temperature (Td)	68	C	Rep. t2 coeff.	k	
8	Response time index (RTI)	80	(m-s)1/2	Slow	0.003	
9	Fire growth power (n)	2	-	Medium	0.012	
10	Fire growth coefficient (k)	0.047	kW/s^n	Fast	0.047	
11	Time step (dt)	2	s	Ultrafast	0.400	
12						
13						
14	Calculation time (s)	HRR	Gas temp	Gas velocity	Det temp	dT/dt
15	0	0.0	20.0	0.00	20.00	0.0000
16	2	0.2	20.2	0.10	20.00	0.0006
17	4	0.8	20.4	0.15	20.00	0.0019
18	6	1.7	20.7	0.20	20.00	0.0037
19	8	3.0	21.0	0.24	20.01	0.0059
20	10	4.7	21.3	0.28	20.02	0.0085
21	12	6.8	21.7	0.32	20.04	0.0114
22	14	9.2	22.0	0.35	20.06	0.0147
112	194	1768.9	87.8	2.03	63.53	0.4335
113	196	1805.6	88.8	2.05	64.39	0.4362
114	198	1842.6	89.7	2.06	65.27	0.4389
115	200	1880.0	90.7	2.08	66.14	0.4415
116	202	1917.8	91.6	2.09	67.03	0.4440
117	204	1956.0	92.5	2.10	67.91	0.4465
118	206	1994.5	93.5	2.12	68.81	0.4490
119	208	2033.4	94.4	2.13	69.71	0.4515
120	210	2072.7	95.4	2.14	70.61	0.4539
121	212	2112.4	96.4	2.16	71.52	0.4563

Calculation time(s)	HRR (KW)	Gas Temp	Gas Velocity	Det. Temp	dT/dt
206	1995	94^0 C	2.12 m/s	68.81^0 C	0.4490

Fig#22, DETACT result of sprinkler response time.

The DETACT model is also shown graphically in Figure # 22 above. Based on the results presented above, a sprinkler will operate in approximately 206 seconds (3.4 minutes) with an approximate HRR of 1995 kW.

Sequence of Fire Alarm Matrix:

The following are indicative of the required operational functionality of the fire alarm system per NFPA 72 in the event of an alarm condition (See Fig# 23B):

1. The system alarm LED shall flash.
2. The local signal in the FACP shall sound.
3. Activation of alarm notification appliances throughout the building.
4. The Municipal master box and/or IP-DACT activated for alarm condition.

5. The LCD display on the FACP and remote annunciator shall indicate all information associated with the fire alarm condition, including the type of alarm point and its location within the protected premises.

6. History data logging shall log the information associated with each new fire alarm control panel condition, along with time and date of occurrence.

7. All system output programs assigned via control-by-event equations to be activated by the particular point in alarm, shall be executed and the associated system outputs (alarm notification appliances and/or relays) activated. System outputs could include:

i. Firefighter's communications enabled.

ii. Elevator capture/recall enabled.

iii. Elevator power shunt trip enabled.

iv. Smoke control/fan shutdown enabled.

v. Public address system shutdown enabled.

vi. House lights in Public spaces raised to full-on levels.

vii. Door release/release locks on normally locked egress doors.

A. The following are indicative of the required operational functionality of the fire alarm system per NFPA 72 in the event of a supervisory condition:

1. The system supervisory LED shall flash.

2. A pulsing alarm tone in the control unit shall sound.

3. The display shall indicate all information associated with the supervisory condition, including device, its location within the protected premises, and the time and date of that activation.

4. If more supervisory signals are in the system, the operator shall be able to scroll the display to view new signals.

5. All system output programs assigned via control-by-event equations to be activated by the particular point monitored shall be executed, and the associated system outputs (Supervisory Notification Appliances and/or relays) shall be activated.

B. The following are indicative of the required operational functionality of the fire alarm system per NFPA 72 in the event of a trouble condition:

1. The system trouble LED shall flash.

2. A tone in the control unit shall sound.

3. The display shall indicate all information associated with the trouble condition, including type

of trouble point, its location within the protected premises, and the time and date of that activation.

4. All system output programs assigned via control-by-event equations to be activated by the particular point in trouble shall be executed, and the associated System Outputs (Trouble Notification Appliances and/or relays) shall be activated.

Smoke control:

There are various uses to which smoke control systems can be put in the case of a fire in warehouses and factory building.

1. To facilitate escape by providing smoke free escape routes.
2. To reduce the likelihood of damage or loss to production or stock.
3. To enable the fire-fighters to better see the fire and therefore to extinguish it more speedily and effectively.
4. To permit greater travel distances to exits to be designed in, without the need for compartmentation, resulting in a larger or more open building plan. Where travel distances cannot be achieved under Building Regulations, Smoke control can be introduced as a compensatory feature.

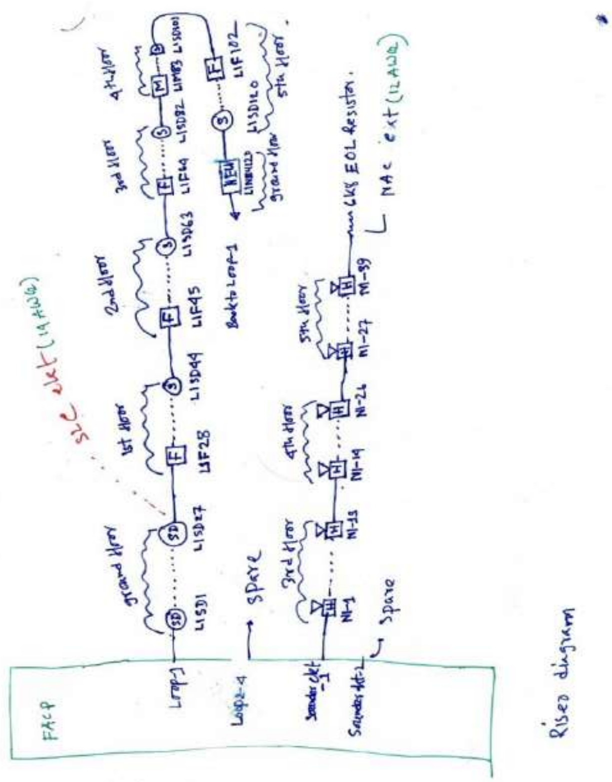
In this building, travel distance meets the code. So, natural ventilation system is used. No duct detector is used and fire rated doors shall be automatic-closing by actuation of a smoke detector. Smoke proof enclosures using natural ventilation shall comply with relevant section of NFPA 101 (7.2.3.3 of NFPA101).

Inspection and Maintenance Requirements:

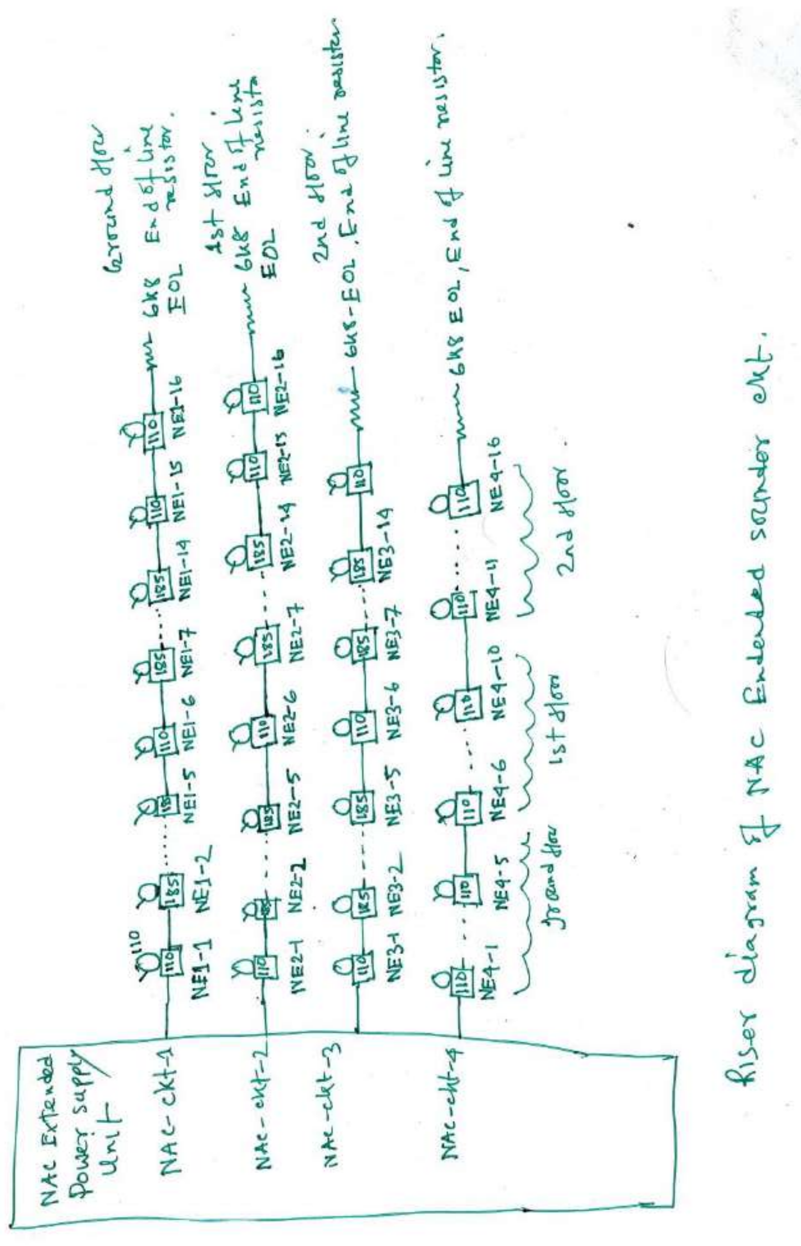
NFPA 72 requires all new systems to be inspected and tested. This initial inspection/ test is commonly referred to as an “acceptance test”. An acceptance test, in accordance with Chapter 14 of NFPA 72, was conducted on MPB’s fire detection system shortly after it was installed. This initial inspection was completed to ensure the correct equipment was installed in a manner that complied with the approved design documents. In addition, all functions of the system were tested to verify they operated properly.

After the acceptance test, the fire alarm system must be continuously inspected, tested, and maintained in order to ensure operational readiness and proper performance. Chapter 14 of NFPA 72 requires the building/ system owner, or the owner’s designated representative, to have an inspection, testing and maintenance program that satisfies the manufacturer’s published instructions, as well as, the requirements of NFPA 72.

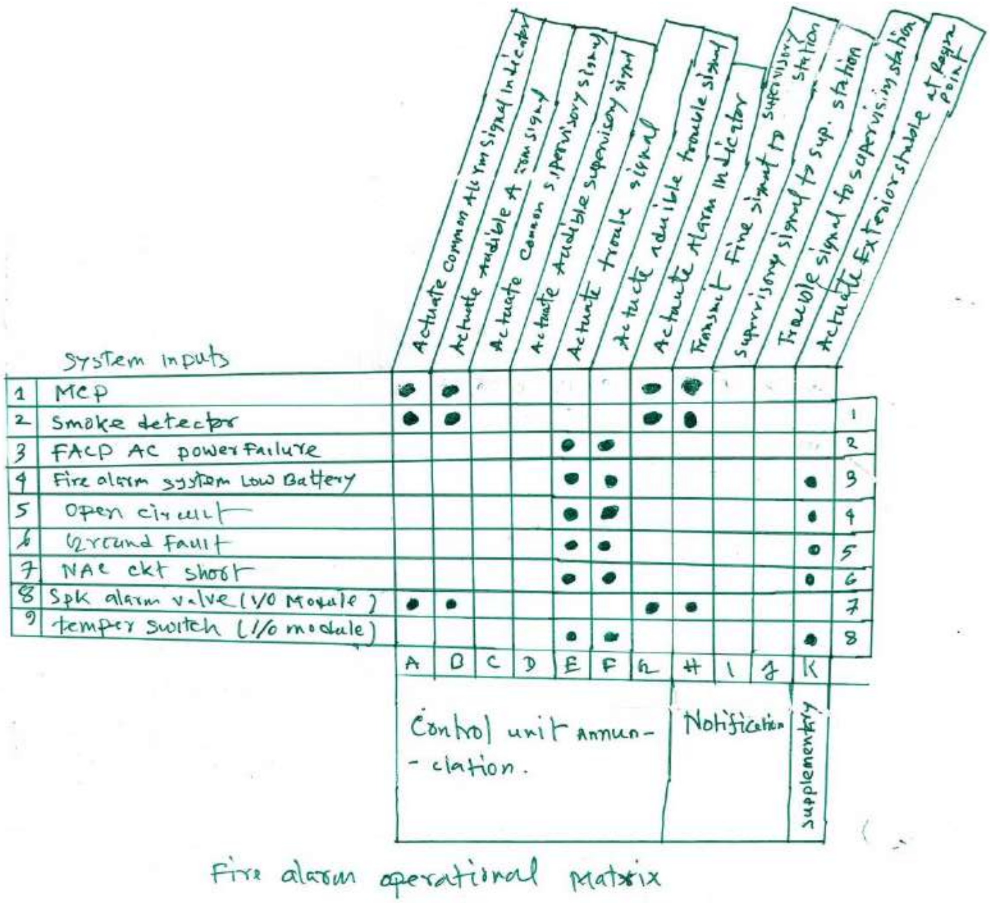
Fire alarm input/output matrix and BPB Building's layout are shown in Fig#23 & Fig#23A-M and Fire alarm Catalog is shown in Appendix -9. Fire Alarm Layout for MPB Building is shown in below Appendix#2.



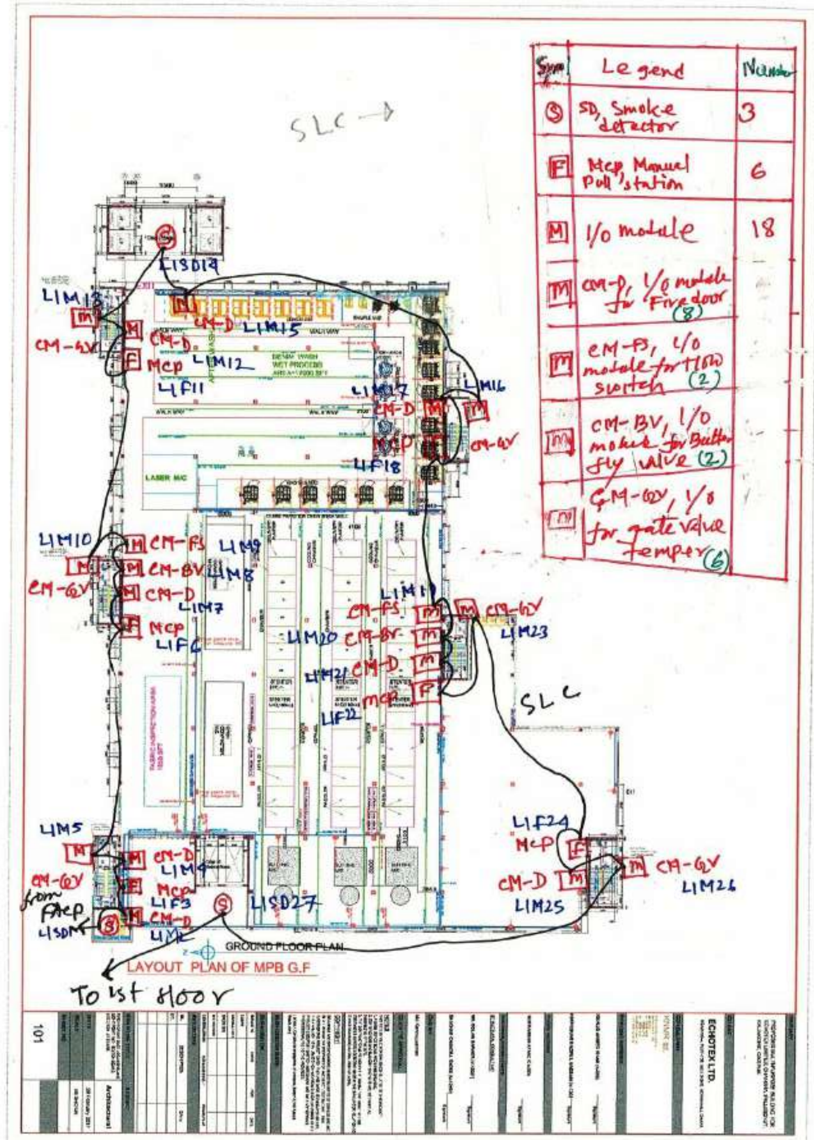
Fig#23: Riser diagram of SLC (Loop-1) and NAC-Ckt-1 in FACP.



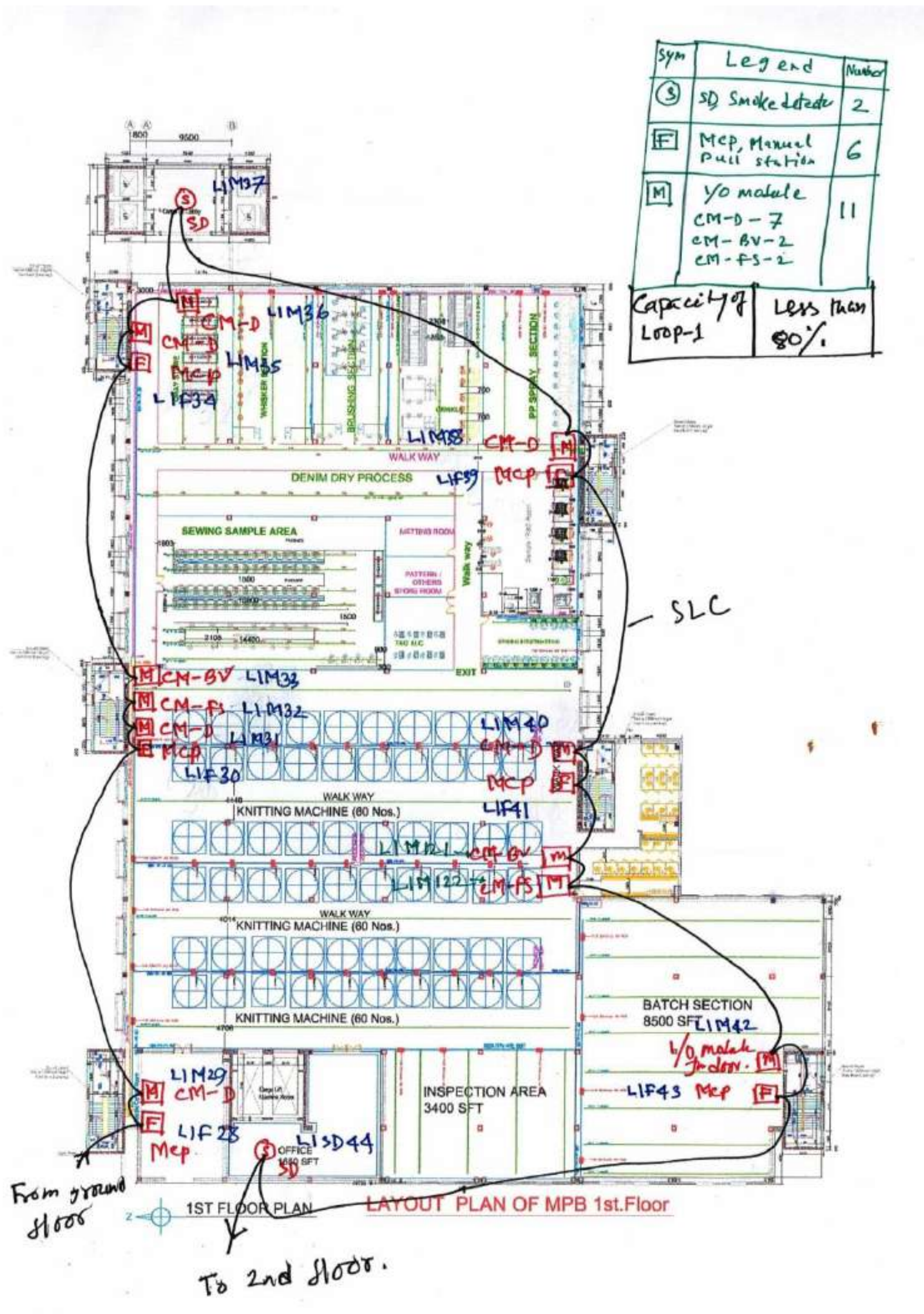
Fig#23A: Riser diagram of Notification Devices in NAC power Extended.



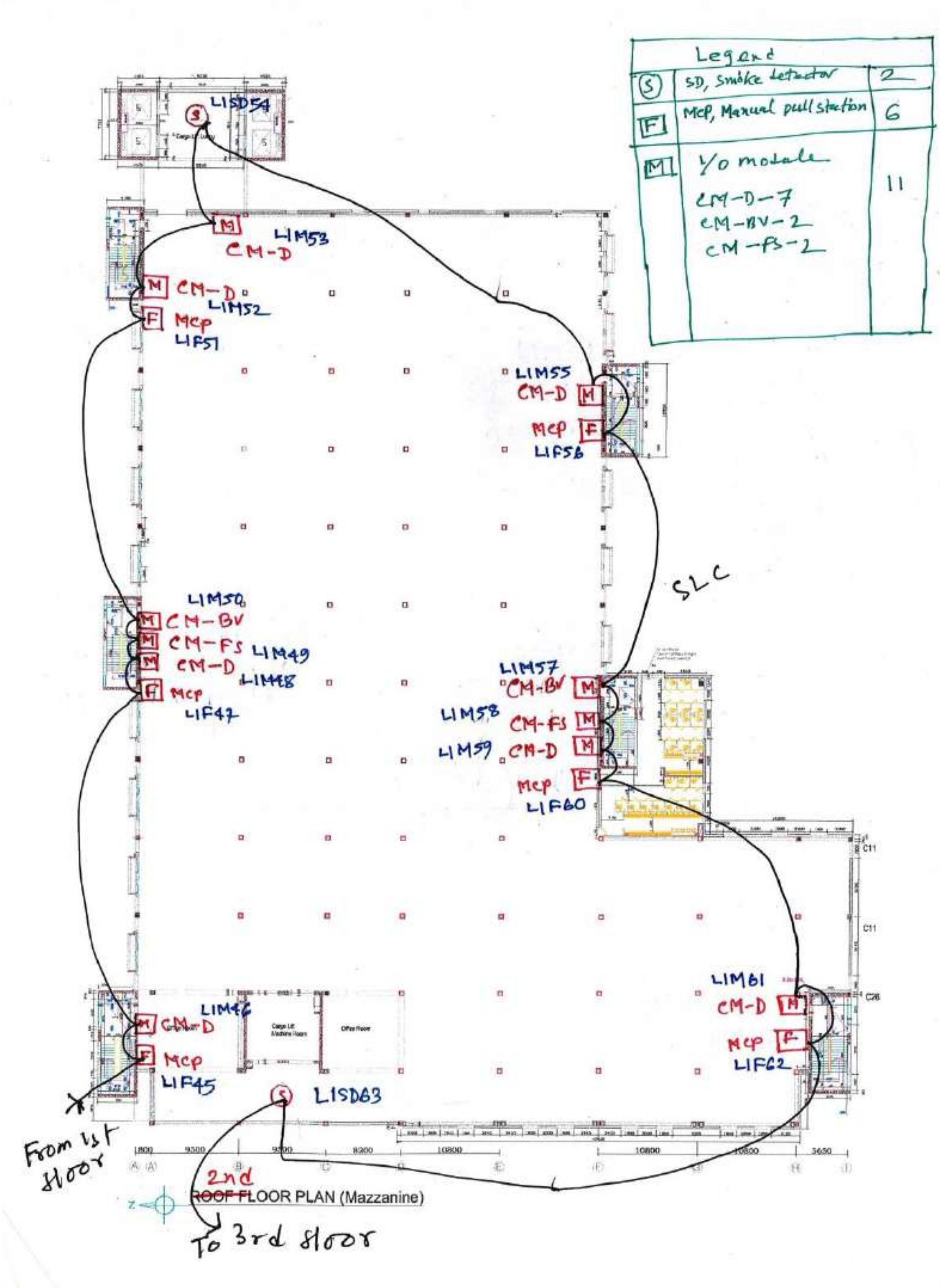
Fig#23B: Fire Alarm Operational Matrix.



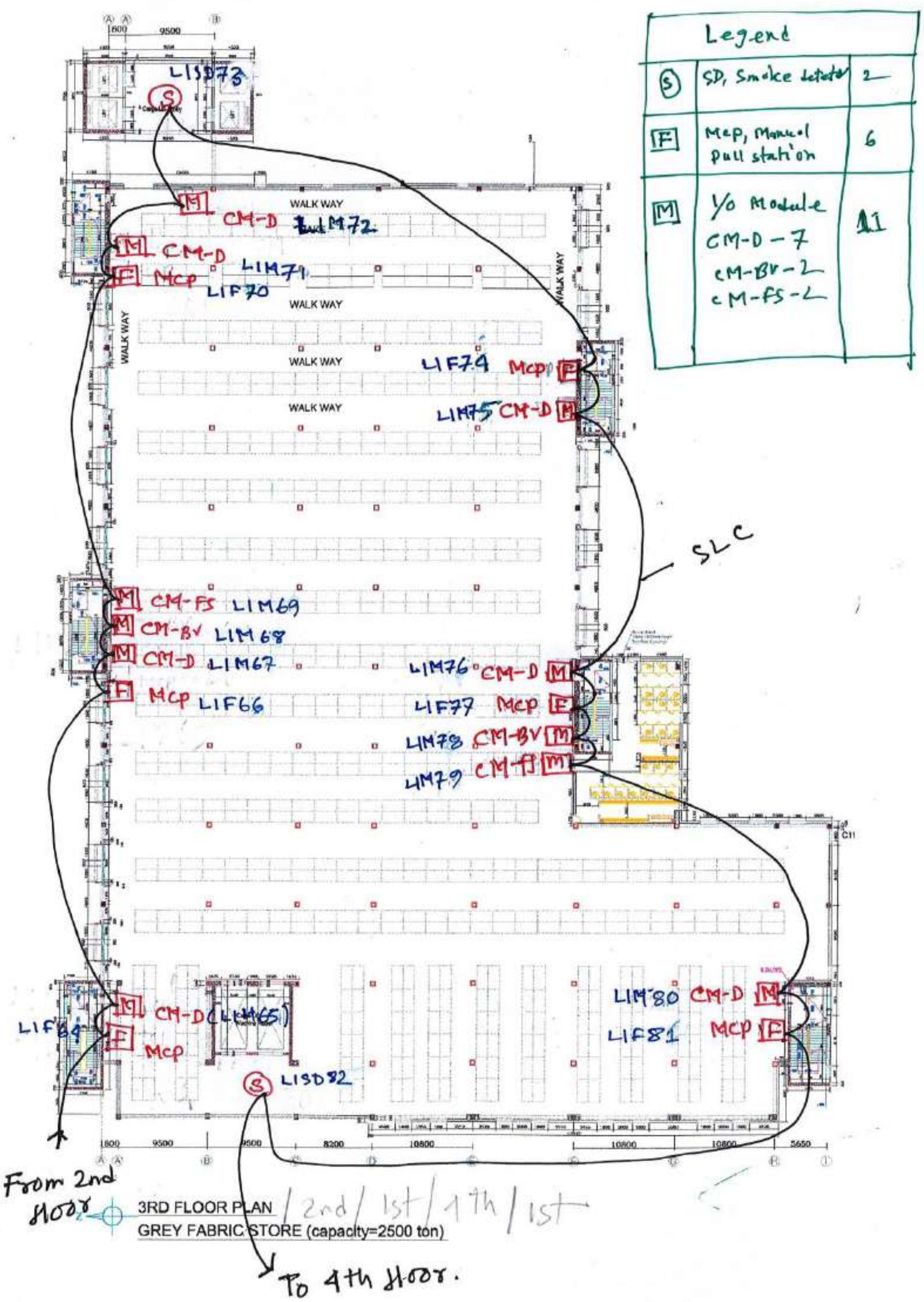
Fig#23C: Initiation Device plan (SLC) in Ground Floor.



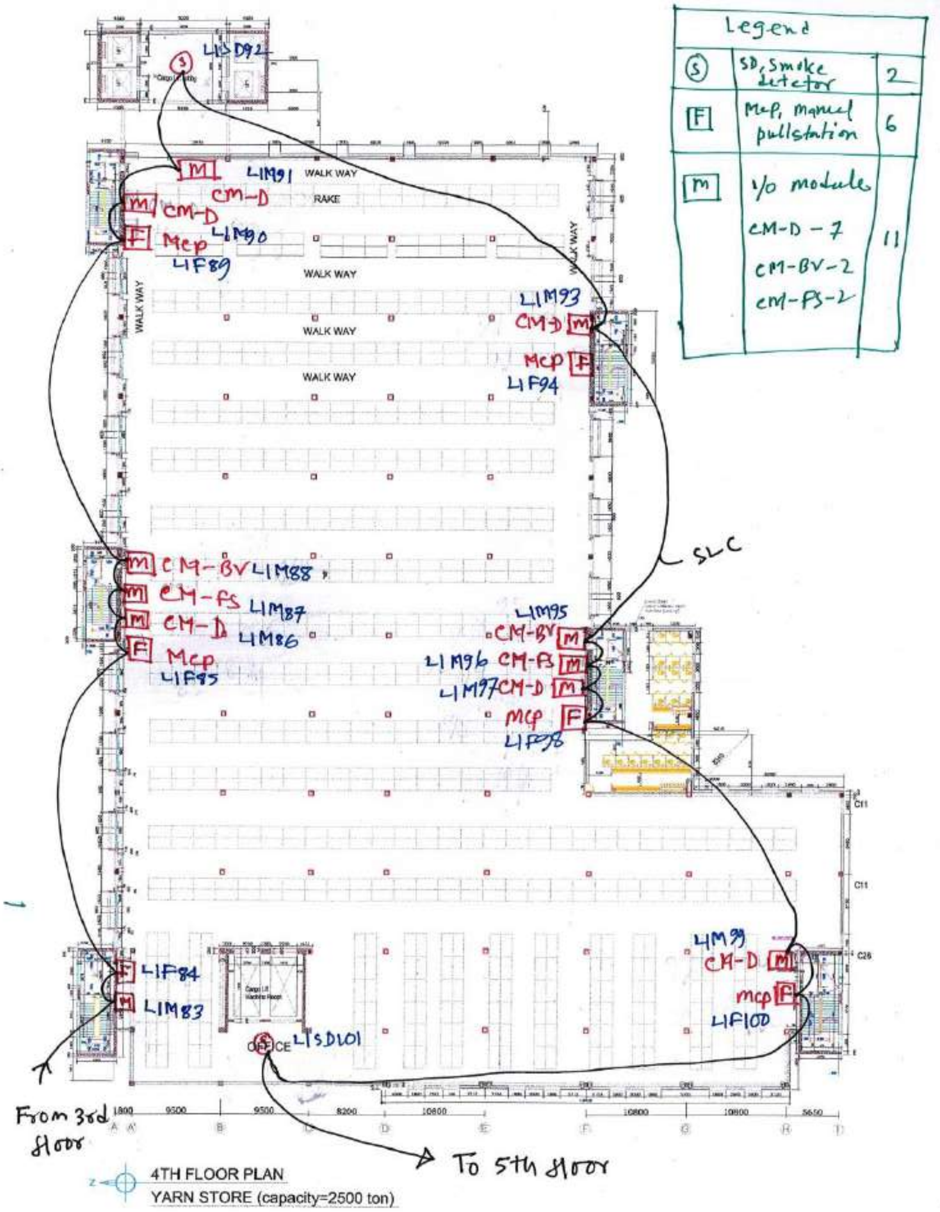
Fig#23D: Initiation Device plan (SLC) in 1st Floor.



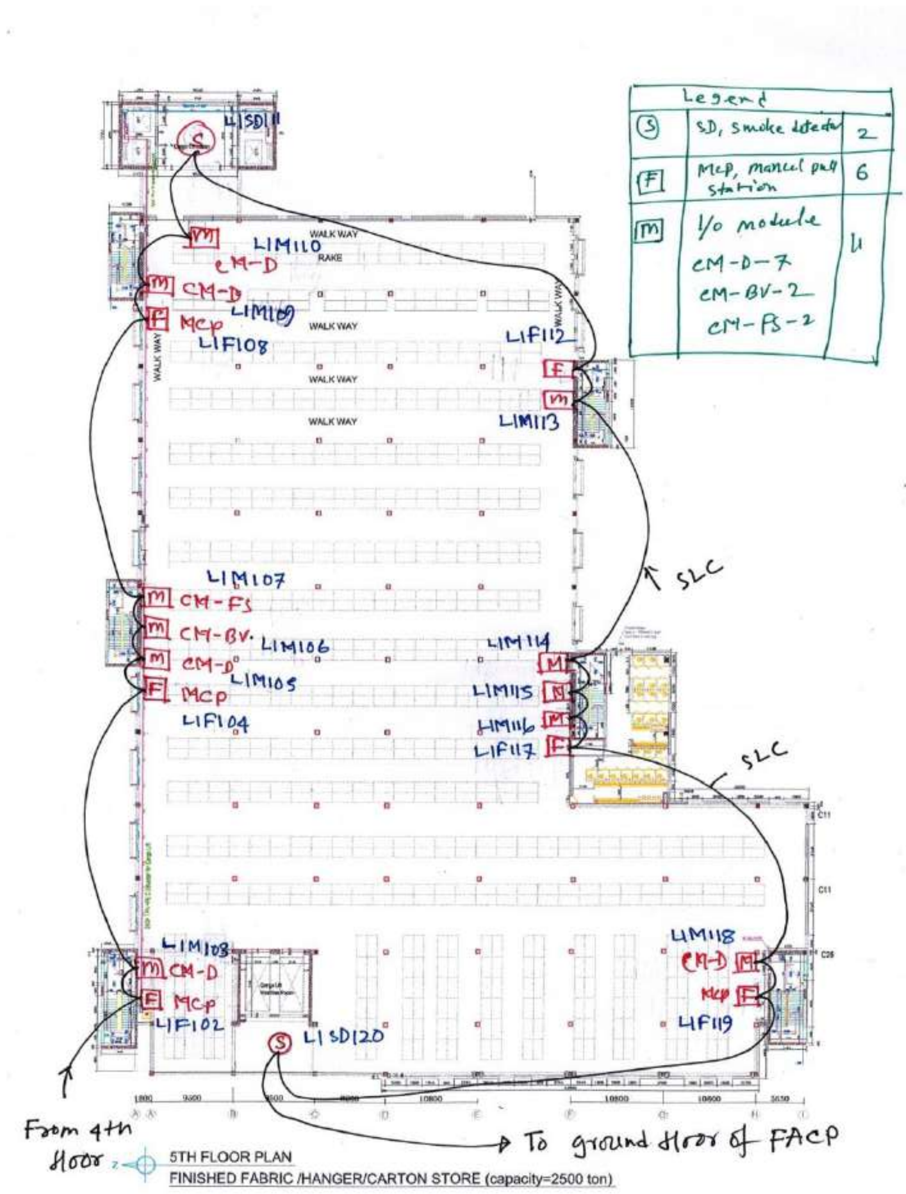
Fig#23E: Initiation Device plan (SLC) in 2nd Floor.



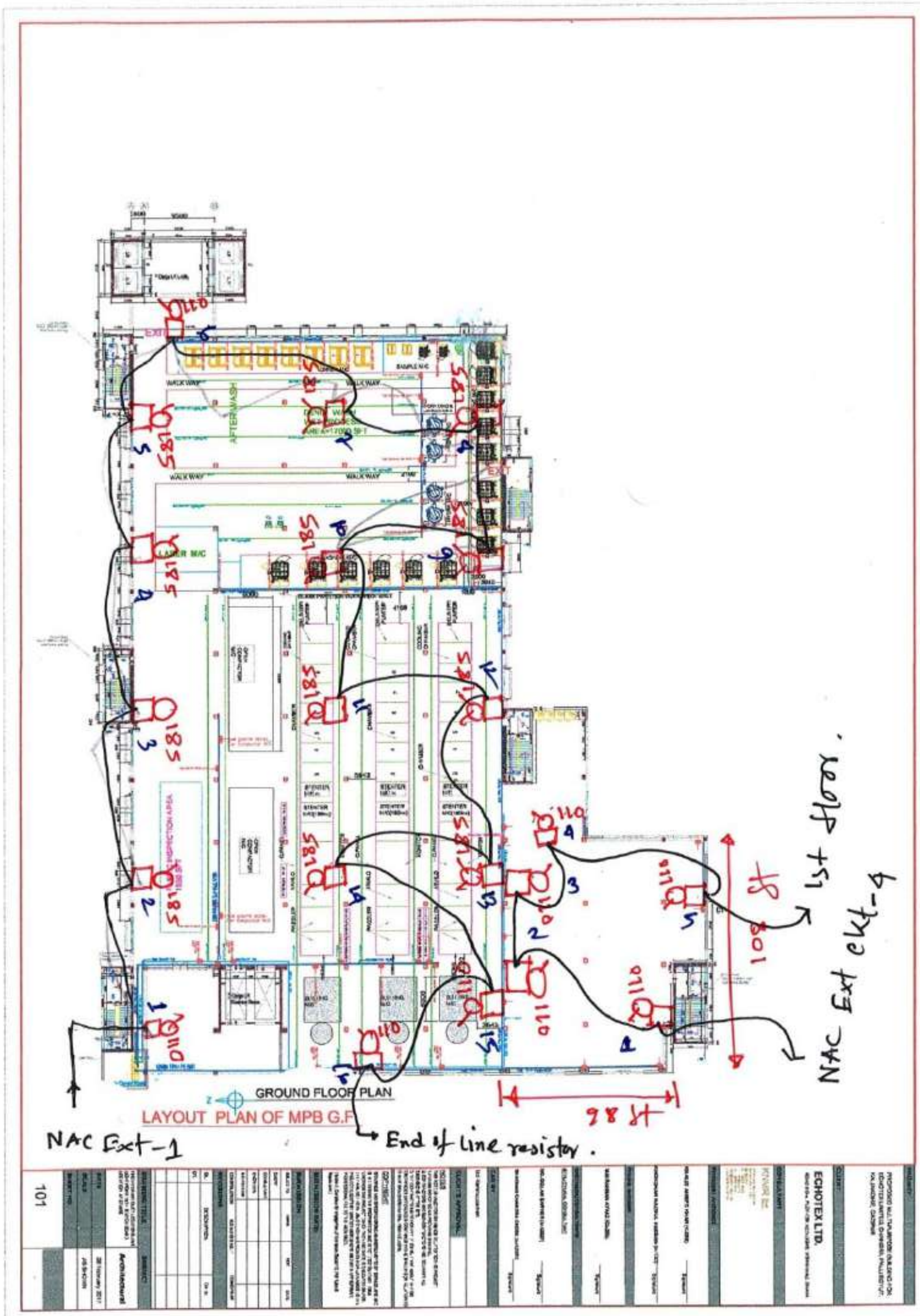
Fig#23F: Initiation Device plan (SLC) in 3rd Floor.



Fig#23G: Initiation Device plan (SLC) in 4th Floor.



Fig#23H: Initiation Device plan (SLC) in 5th Floor.



Fig#23I: Notification Device plan in Ground Floor.

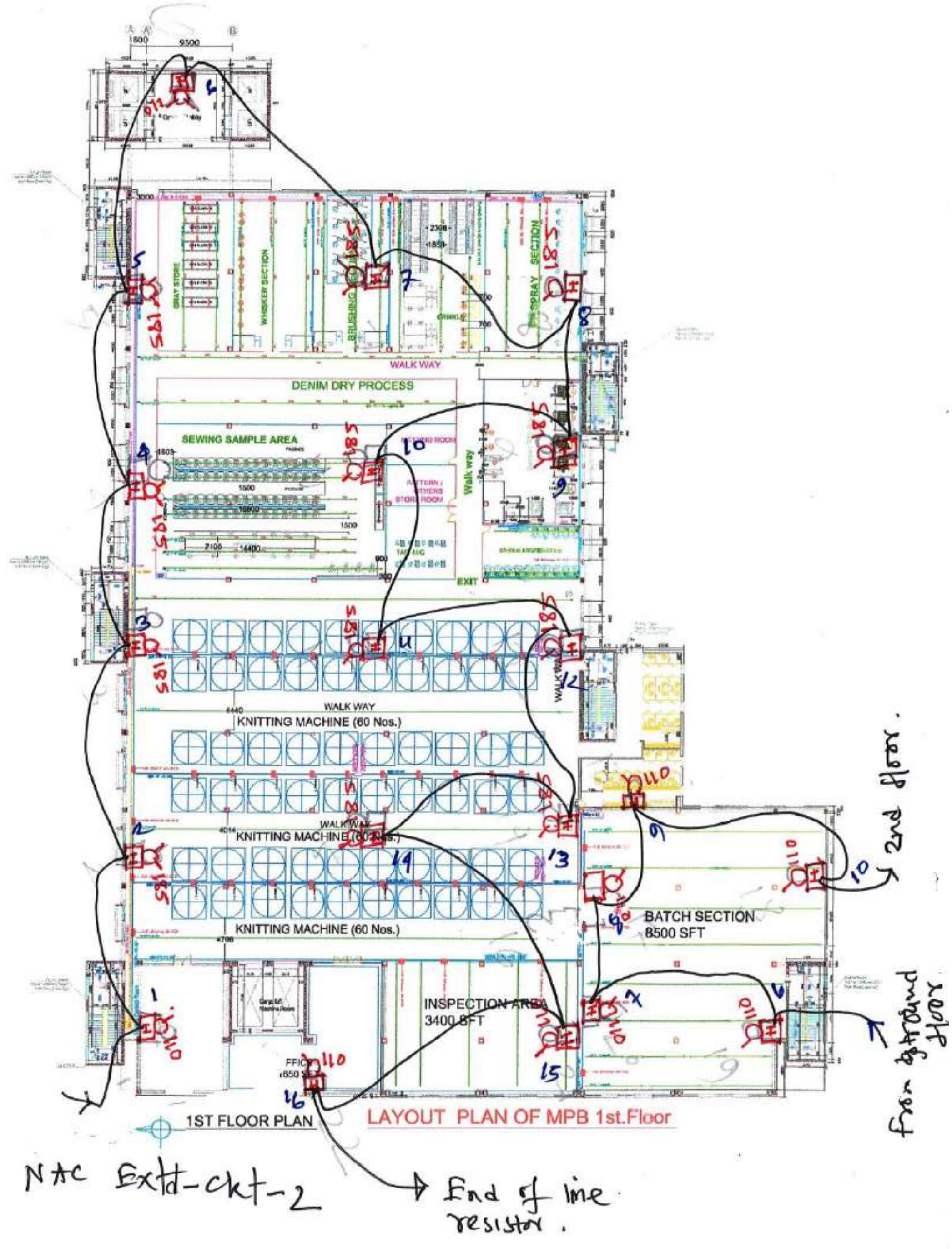
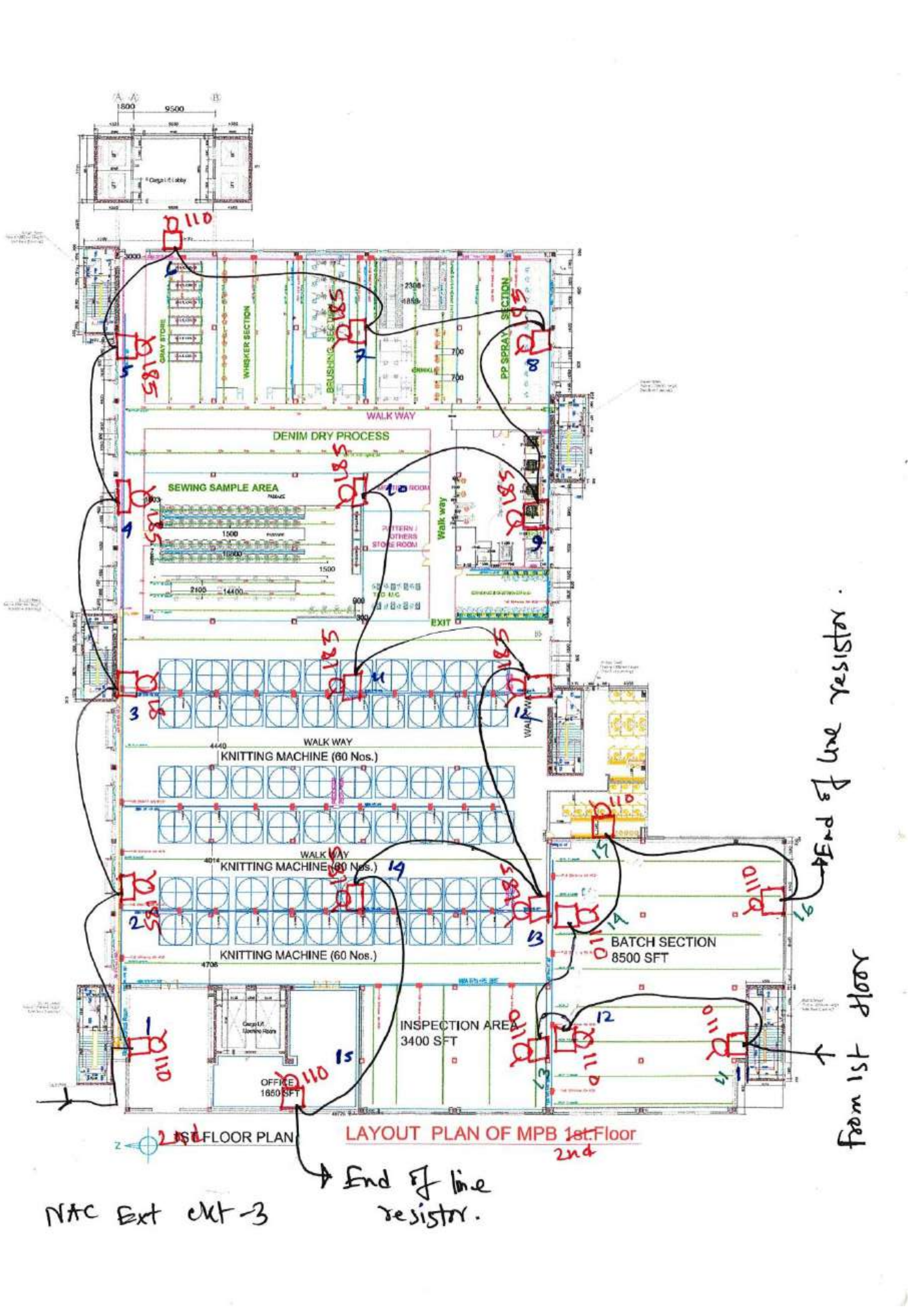
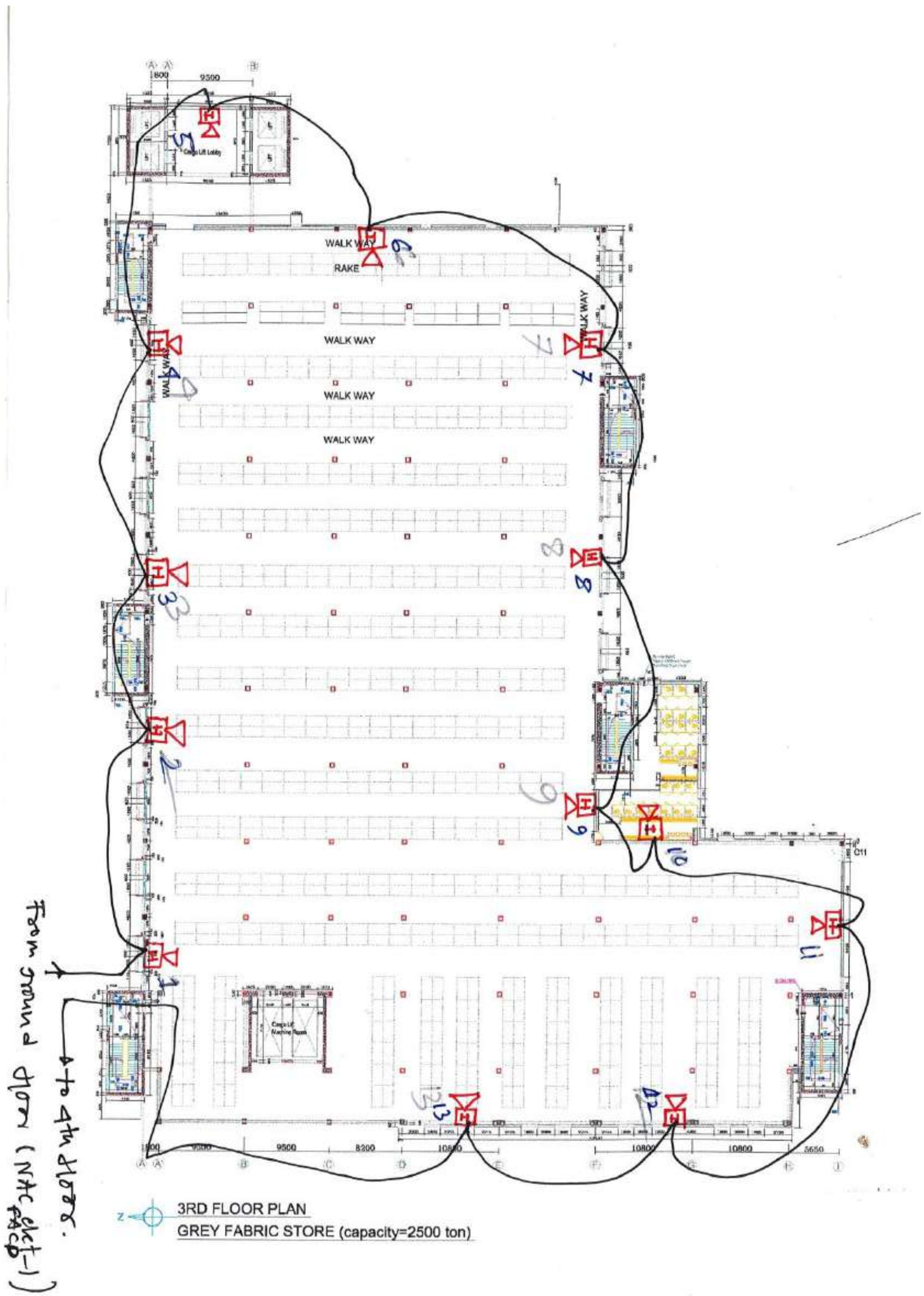


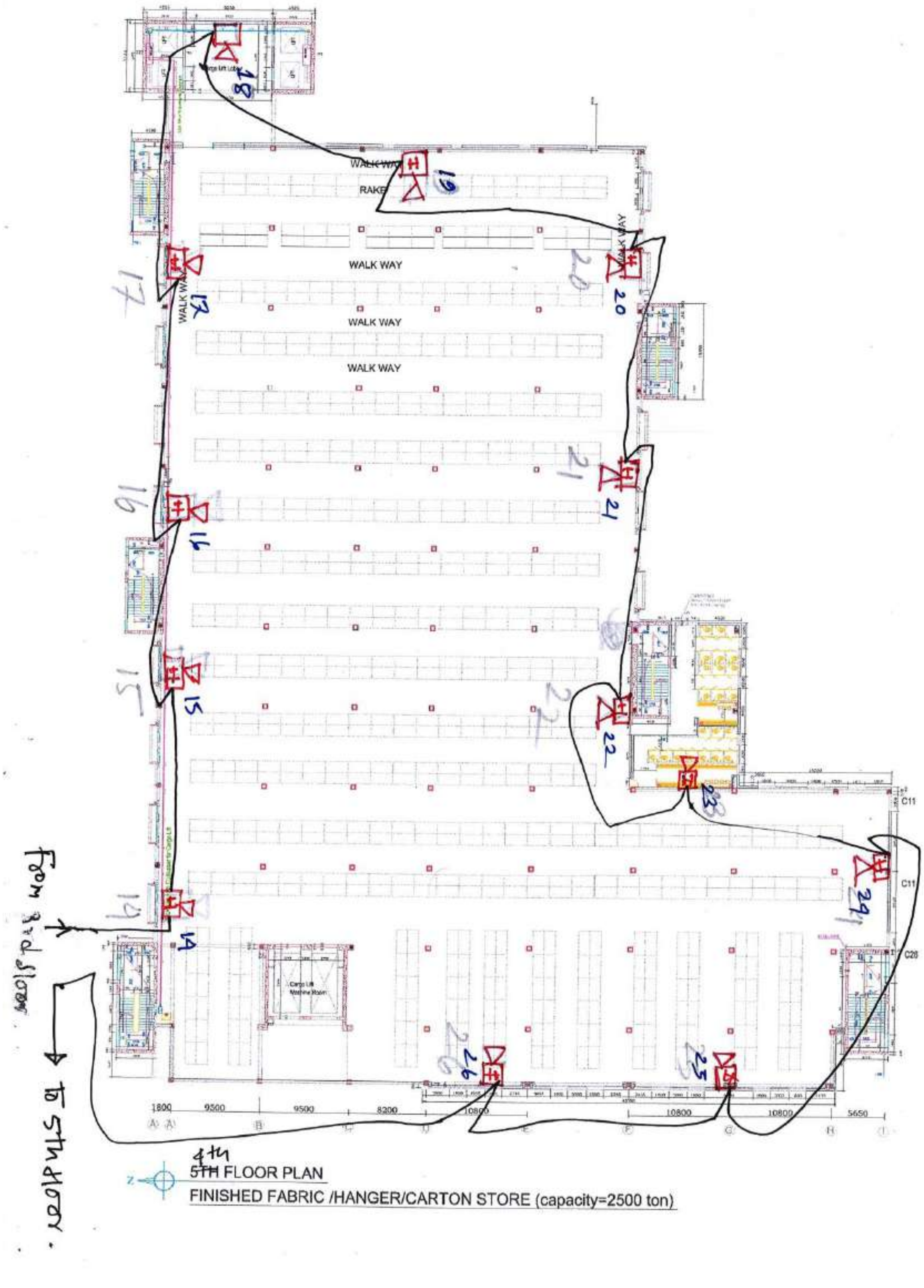
Figure: Notification Device plan in 1st Floor.



Fig#23J: Notification Device plan in 2nd Floor.



Fig#23K: Notification Device plan in 3rd Floor.



Fig#23L: Notification Device plan in 4th Floor.

Fig#23M: Notification Device plan in 5th Floor.

Section Summary - Fire Detection, Alarm and Communication Systems:

The panel is the “hub” of the fire alarm system. This is where the system can be programmed according to the users’ requirements, monitors device operation, indicates if there is a problem and identifies where the fire alarm system has been activated. This system is capable of communicating with devices and performing process management tasks such as shutting down the HVAC system, unlocking doors, recalling elevators, etc. The locations of initiating devices and notification devices were evaluated and found to comply with pertinent codes. Several measures were taken to ensure the system could provide intelligible emergency voice/alarm communications. Calculations were conducted to verify secondary power requirements were met.

Flammability Assessment

4.1 Interior Finish and Flammability Assessment

Building codes control the flammability of interior finishes (interior linings) to limit early fire development, where occupants may be impacted during their egress. By controlling flammability and smoke development of finishes, fire growth can be slowed, and building occupants can take longer to evacuate in tenable conditions. NFPA has three primary documents that address interior finishes, including NFPA 101®, Life Safety Code®, NFPA 1, Fire Code, and NFPA 5000®, Building Construction and Safety Code®. Although the International Building Code (IBC) and the International Fire Code (IFC) of the International Code Council (ICC) approach the subject differently, the requirements end up being similar and, in many cases, identical.

Ensuring that the MPB building is well designed and safe can be easily diminished if attention is not given to details like interior finishes. Flammability of interior finish materials must be taken into consideration when selecting what will be used to avoid using products that can generate excessive amount of toxicity, smoke and heat in a fire scenario. In this section the prescriptive code requirements for interior finishes along with the tests behind there regulations will be discussed. Interior wall and ceiling finish materials must be classified for fire performance and smoke development in accordance with ASTM E84 or UL 723. These materials are grouped into one of three classes based on the material's flame spread and smoke- development indexes. Permitted materials are based upon the occupancy classification, as well as the location where the material is to be installed. For example, materials with a lower flame spread index may be required for exit stairways than would be required for ordinary rooms.

The classifications of interior finishes are based on flame spread and smoke development indices which are shown below (Table 20).

Table 20: Wall & Ceiling Finishes Classifications

Finish Class	Flame spread /smoke development	Index
A	Flame spread index	0-25
	smoke development index	0-450
B	Flame spread index	26-75
	smoke development index	0-450
C	Flame spread index	76-200
	smoke development index	0-450

The MPB building is sprinklered, Table 803.9 of the IBC (see Table 21) permits enclosure spaces to have a wall & ceiling finish classification of A, B or C. Interior exit stairways/ ramps, exit passageways, corridors and enclosures for exit access stairways/ ramps must be Class A or B. All of the wall and ceiling finishes within the MPB meet these requirements.

Table 21. Interior Wall & Ceiling Finish Requirements by Occupancy

GROUP	SPRINKLERED[i]			NONSPRINKLERED		
	Interior exit stairways, interior exit ramps and exit passageways[a, b]	Corridors and enclosure for exit access stairways and exit access ramps	Rooms and enclosed spaces[c]	Interior exit stairways, interior exit ramps and exit passageways[a, b]	Corridors and enclosure for exit access stairways and exit access ramps	Rooms and enclosed spaces[c]
A-1 & A-2	B	B	C	A	A[d]	B[c]
A-3[f], A-4, A-5	B	B	C	A	A[d]	C
B, E, M, R-1	B	C	C	A	B	C
R-4	B	C	C	A	B	B
F	C	C	C	B	C	C
H	B	B	C[g]	A	A	B
I-1	B	C	C	A	B	B
I-2	B	B	B[h, i]	A	A	B
I-3	A	A[j]	C	A	A	B
I-4	B	B	B[h, i]	A	A	B
R-2	C	C	C	B	B	C
R-3	C	C	C	C	C	C
S	C	C	C	B	B	C
U	No restrictions			No restrictions		

4.2 Summary of Flammability:

Looking at the interior finishes in MPB, the building is very simplistic. The floors are concrete and the walls are Brick wall board. Looking at the flame spread rating for these materials; the interior finishes based on ASTM 84 must meet Class B and C.

Flammability restrictions, as required by the LSC, on interior wall and ceiling finish materials were evaluated. No deficiencies related to fire resistance were identified.

In addition to limiting the flammability of finishing materials, a fire suppression system was also installed throughout the MPB Building to limit the spread of a fire event.

Fire Suppression Systems

5.1 Fire Suppression Systems

Fire Suppression system is essential to saving lives and protecting property. Fire sprinkler systems often serve as the first line of defense against smoke and fires preventing the spread of the fire beyond the immediate area of origin until the fire can be extinguished. The fire can be extinguished by either the sprinkler system alone or with intervention from firefighting personnel. This section will review the fire sprinkler system design requirements for the MPB building.

Fire Suppression system applicable codes include:

- 2018 International Building Code;
- 2018 International Fire Code;
- 2019 Standard for the Installation of Sprinkler Systems (NFPA 13); and,
- 2019 Standard for the Installation of Standpipe and Hose Systems (NFPA 14).

<u>Automatic Fire Sprinkler System</u>

Automatic sprinkler systems have sustained an enviable record of protecting life and property for over 100 years. An automatic sprinkler system is designed to detect a fire and extinguish it with water in its early stages or hold the fire in check so that it can be extinguished by other means. A sprinkler system consists of a water supply (or supplies) and one or more sprinkler installation. Each installation consists of a set of valves and a pipe array fitted with sprinkler heads. This section will review the fire sprinkler system design requirements for the MPB building.

Code Requirements for Automatic Sprinkler in these New Buildings:

The main occupancy of this MPB building is factory occupancy F-1, moderate hazard storage. Per IBC section 903.2.4, an automatic sprinkler system shall be provided throughout the building where “A Group F-1 area is located more than three stories above grade plane” or fire area exceeds more than 13000 square feet (1115 SM) or fire area is located more than three stores above grade plane or fire area on all floors exceeds 24000 square feet (2230 m^2).

An automatic sprinkler system shall be provided throughout all building containing group S-1 occupancy where one of the following condition exists (IBC 903.2.9): if fire area exceeds 12000 square feet (1115 m^2) or located more than three stories above grade plane or fire area on all floors exceeds 24000 square feet (2230 m^2).

NFPA 13 defines an automatic sprinkler as “A fire suppression or control device that operates automatically when its heat-activated element is heated above its thermal rating, allowing water to discharge over a specific area. A wet pipe fire sprinkler system is designed for the MPB building. A wet pipe sprinkler system is defined as “A sprinkler system employing automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers activated by heat from a fire.” The water source used in this design comes from a fire pump and dedicated water tank for the fire pump.

Hazard classification:

NFPA 13 provides the requirements for the design of fire sprinkler systems. The basic outline for fire sprinkler design is as follows:

- Section 4.3.1.1 and 4.3.1.2: Identify the occupancy/ hazard group for the most hazardous conditions expected. This occupancy/hazard classification will be applied to the fire sprinkler system design only.
- Determine the water demand based on section 19.2.4.1 which provides three different options
- Provide hydraulic calculations demonstrating that the available water supply is adequate based on Chapter 27.

MPB building will contain light hazard occupancy, ordinary hazard (group 2) and class III category hazards.However, light hazard occupancy size is very small, so we provide Ordinary Hazard -2 calculation.

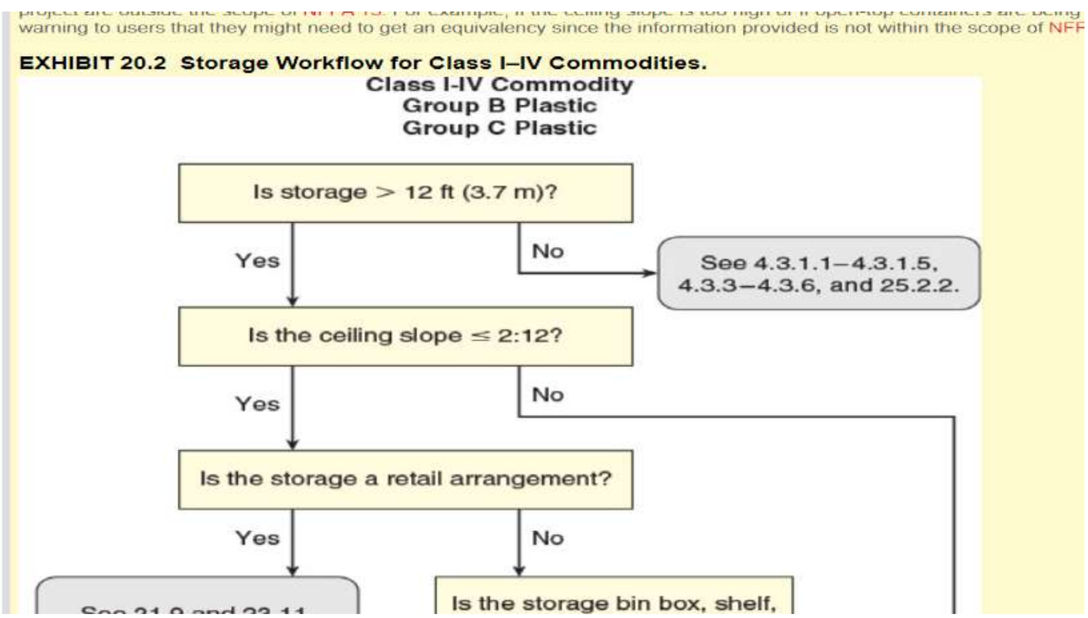
- 4.3.4 Ordinary (Group 2) occupancies shall be defined as occupancies or portions of other occupancies where quantity and combustibility of contents are moderate to high, stockpiles of contents with moderate rates of heat release do not exceed 12ft (3.66 m), and stockpiles of contents with high rates of heat release do not exceed 8 ft. (2.4m).

- MPB building has 11 ft. cotton or polyester rack storage in third, fourth and fifth floors. As per NFPA 13 Table A.20.4 (b), this is class III commodity (See Table#22 and Fig#24).

Table#22: Commodity Classification.

Table A.20.4(b) *Continued*

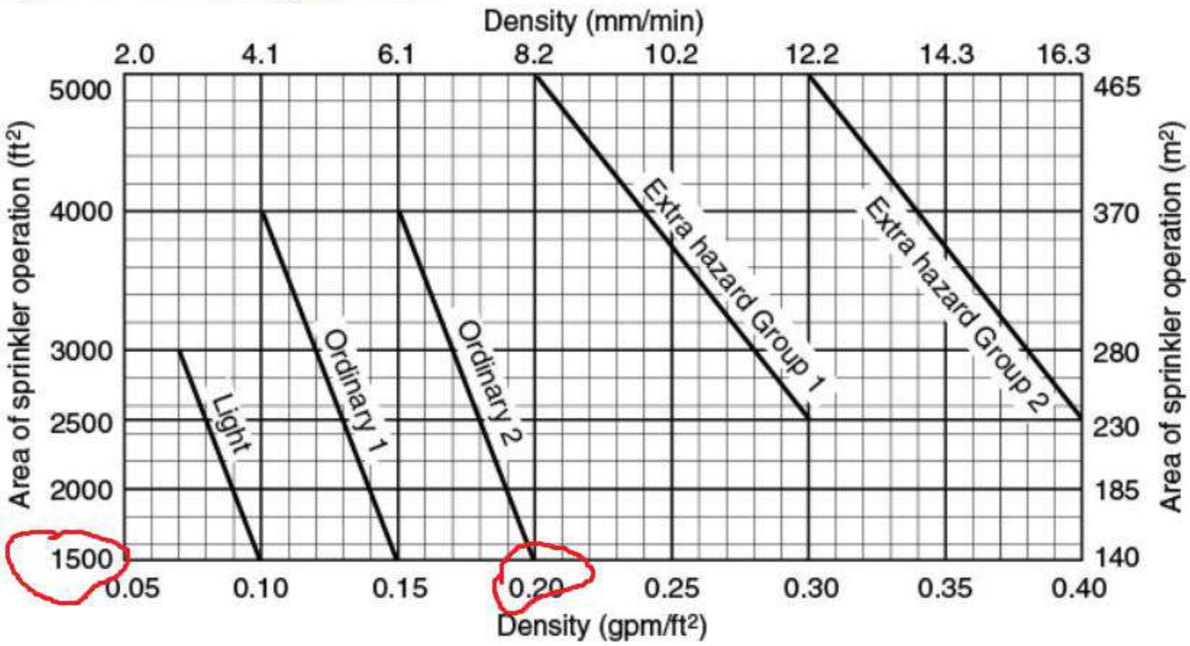
Product Heading	Product	NFPA 13
	Powders; noncombustible; glass bottles or jars; cartoned	Class I
	Powders; noncombustible; PET bottles or jars	Class II
	Powders; noncombustible; plastic (other than PET) bottles or jars; exposed	Group A Nonexpanded
	Powders; noncombustible; plastic bottles or jars greater than 1 gal (4 L) capacity	Group A Nonexpanded
	Powders; noncombustible; plastic bottles or jars up to 1 gal (4 L) capacity; cartoned	Class IV
Textile Materials/Products	Cloth; natural fibers; baled	Class III
	Cloth; synthetic cloth	Group A Nonexpanded
	Clothing; natural fibers (e.g., wool, cotton) and viscose	Class III
	Cotton; cartoned	Class III
	Diapers; cotton or linen	Class III



Fig#24: Storage workflow for Class I-IV Commodities.

The 12 ft (3.7 m) high warehouse storage is considered a Class III commodity and needs to be protected in accordance with the criteria for ordinary hazard (Group 2) occupancies (see Fig#25).

Figure 19.3.3.1.1 Density/Area Curves.



Fig#25: Density /Area Curve (reference 19.3.3.1.1 of NFPA 13).

Selection of density /area: Based on OH-2, 0.20 gpm/ft^2 is required for most remote/demanding of 1500sft. For densities of 0.20 gpm/ft^2, standard response sprinkler with Factor = 8 is selected.

Table#23: Hose Demand based on Storage Commodity Classification.

Commodity	Type of Storage	Storage Height		Maximum Ceiling Height		Design Curve Figure	Note	Inside Hose		Total Combined Inside and Outside Hose		Duration
		ft	m	ft	m	19.3.3.1.1		gpm	L/min	gpm	L/min	(minutes)
Class I to Class IV												
Class I	Solid-piled, palletized, bin box, shelf, single-, double-, multiple-row rack, and back-to-back shelf storage	≤12	≤3.7	—	—	OH1		0, 50, 100	0, 190, 380	250	950	90
Class II		≤10	≤3.0	—	—	OH1		0, 50, 100	0, 190, 380	250	950	90
Class II		>10 to ≤12	>3.0 to ≤3.7	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
Class III		≤12	≤3.7	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
Class IV		≤10	≤3.0	—	—	OH2		0, 50, 100	0, 190, 380	250	950	90
Class IV	Palletized, bin box, shelf, and solid-piled	>10 to ≤12	>3.0 to ≤3.7	32	10	OH2		0, 50, 100	0, 190, 380	250	950	90
	Single-, double-, multiple-row rack and back-to-back shelf storage	>10 to ≤12	>3.0 to ≤3.7	32	10	EH1		0, 50, 100	0, 190, 380	500	1900	120
	Single-, double-, multiple-row rack	>10 to ≤12	>3.0 to ≤3.7	32	10	See Chapter 25.	+1 level of in-rack	0, 50, 100	0, 190, 380	250	950	90

Where the system is a combined sprinkler/standpipe system (Class I or Class III) and the building is fully sprinklered in accordance with NFPA 13, no inside hose demand shall be required at any of the standpipe outlets (Table#23 , 19.2.6.3.1 of NFPA 13).

19.2.6.4 * When hose valves for fire department use are attached to wet pipe sprinkler system risers in accordance with 16.15.2, the following shall apply:

(1)The sprinkler system demand shall not be required to be added to standpipe demand as determined from NFPA 14.

(2)Where the combined sprinkler system demand and hose stream allowance of Table 19.3.3.1.2 exceeds the requirements of NFPA 14, this higher demand shall be used.

(3)For partially sprinklered buildings, the sprinkler demand, not including hose stream allowance, as indicated in Figure 19.3.3.1.1 shall be added to the requirements given in NFPA 14.

For a completely sprinklered building using a combined sprinkler and standpipe riser, the pressure and flow demand for the standpipe system, in most cases, exceeds the demand of the sprinkler system. In such cases, the total water demand for hydraulically calculating the size of the combined riser(s) is determined based on NFPA 14, Standard for the Installation of Standpipe and Hose Systems, only. The overall sprinkler system, however, is still calculated as determined by NFPA 13. In instances where the sprinkler system demand is greater than the standpipe demand, the sprinkler system demand must be used. It is important to note, however, that NPFA 14 requires both systems to be calculated simultaneously in buildings that are not fully sprinklered.

If a building is only partially sprinklered, which is strongly discouraged by 9.1.1 but is allowed for specific conditions by the building code, the sprinkler demand from NFPA 13 and hose demand from NFPA 14 must be added together to determine the discharge criteria for the combined system. This combined demand is necessary because fires can originate in the nonsprinklered area and grow to the point that they activate nearby sprinklers while still requiring full standpipe water supplies to be available for manual suppression in the unprotected portions of the building.

NFPA14. 7.10.1.1.5 The maximum flow rate shall be 1000 gpm (3785 L/min) for buildings that are sprinklered throughout, in accordance with NFPA 13, and 1250 gpm (4731 L/min) for buildings that are not sprinklered throughout, in accordance with NFPA 13.

The minimum water supply shall be available for the minimum duration specified in Table#24 (reference 19.3.3.1.2, NFPA13).

Table#24: Hose Stream Allowance and Water Duration Requirements for Hydraulically Calculated Systems.

Table 19.3.3.1.2 Hose Stream Allowance and Water Supply Duration Requirements for Hydraulically Calculated Systems

Occupancy	Inside Hose		Total Combined Inside and Outside Hose		Duration (minutes)
	gpm	L/min	gpm	L/min	
Light hazard	0, 50, or 100	0, 190, or 380	100	380	30
Ordinary hazard	0, 50, or 100	0, 190, or 380	250	950	60–90
Extra hazard	0, 50, or 100	0, 190, or 380	500	1900	90–120

The lower duration values in Table 19.3.3.1.2 shall be permitted where the sprinkler system water flow alarm device(s) and supervisory device(s) are electrically supervised and such supervision is monitored at an approved, constantly attended location.

5.2 Water Supply Analysis:

Water supplies for sprinkler systems shall be one of the following or any combination (5.2.1, NFPA13) :

(1)A connection to an approved public or private waterworks system in accordance with 5.2.2

(2)A connection including a fire pump in accordance with 5.2.3

(3)A connection to a water storage tank at grade or below grade installed in accordance with NFPA 22 and filled from an approved source

(4)A connection to a pressure tank in accordance with 5.2.4 and filled from an approved source

(5)A connection to a gravity tank in accordance with 5.2.5 and filled from an approved source

(6)A penstock, flume, river, lake, pond, or reservoir in accordance with 5.2.6

(7)*A source of recycled or reclaimed water where the building owner (or their agent) has analyzed the source of the water and the treatment process (if any) that the water undergoes before being made available to the sprinkler system and determined that any materials, chemicals, or contaminants in the water will not be detrimental to the components of the sprinkler system it comes in contact with

Water will be supplied to the sprinkler system by a fire pump meeting one of the options listed in NFPA 13 Section 5.2.1.

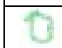
“Water supplies for fire sprinkler system shall be combination from a connection of a fire pump (2) and a water storage tank (3). MPB building has one Fire Department connection located on the ground floor in the pump room towards the back of the building. To ensure the suppression system has an adequate amount of water pressure and water flows from the fire pump. The MPB has a listed diesel driven fire pump (1000 gpm@175 psi) capable of providing the required system pressure during the residual conditions. In addition, a smaller jockey pump maintains system pressure during static conditions. Total water storage tank capacity = 60 min x 1000 gpm=60000 gallons.

Water from the fire pump flows from downstream to system risers/ standpipes. A system riser is a section of vertical piping that contains a control valve, a drain, pressure gauge and a water-flow alarm and supplies water to the sprinkler system.
The maximum floor area on any one floor to be protected by sprinklers supplied by any one sprinkler system riser or combined system riser shall be as follows (4.5.1, NFPA13, 2019):

1. (1)Light hazard — 52,000 ft^2 (4830 m^2)
2. (2)Ordinary hazard — 52,000 ft^2 (4830 m^2)
3. (3)Extra hazard — Hydraulically calculated — 40,000 ft^2 (3720 m^2)
4. (4)High-piled Storage — High-piled storage (as defined in 3.3.95) and storage covered by other NFPA standards — 40,000 ft^2 (3720 m^2)
5. (5)In-rack Storage — 40,000 ft^2 (3720 m^2)

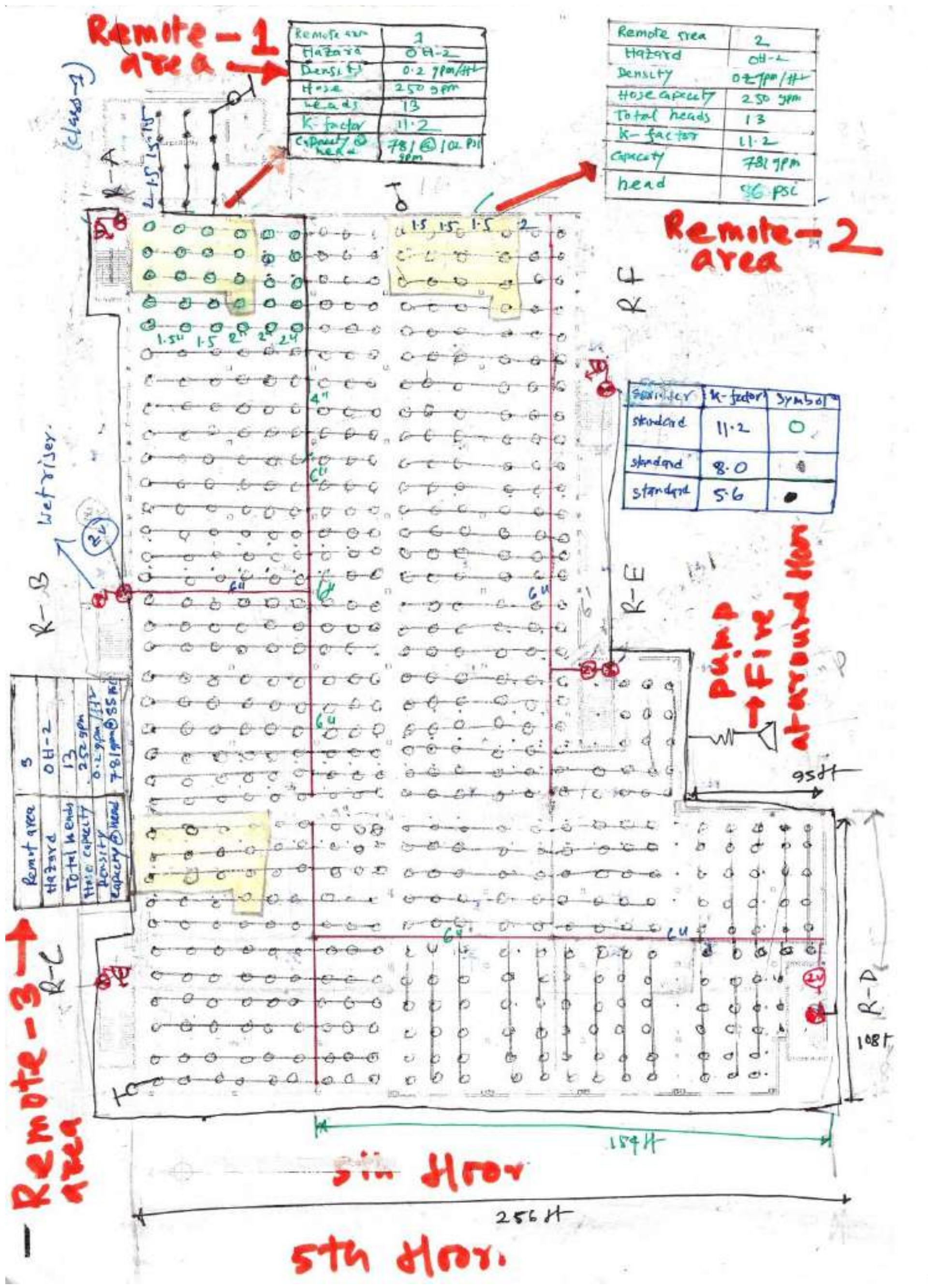
So, a single sprinkler system riser can protect a maximum floor area of 52,000 ft^2. Since the MPB’s floor area exceeds this limitation, more than one system riser was required. The last component of the suppression system is the sprinkler head itself. Various styles of sprinklers (upright with k-factor of 11.2, 8 & 5.6) were installed throughout the MPB building to satisfy different design challenges present at specific locations. Sprinkler types are shown below (see Table 25).

Table25: Sprinkler Specification.

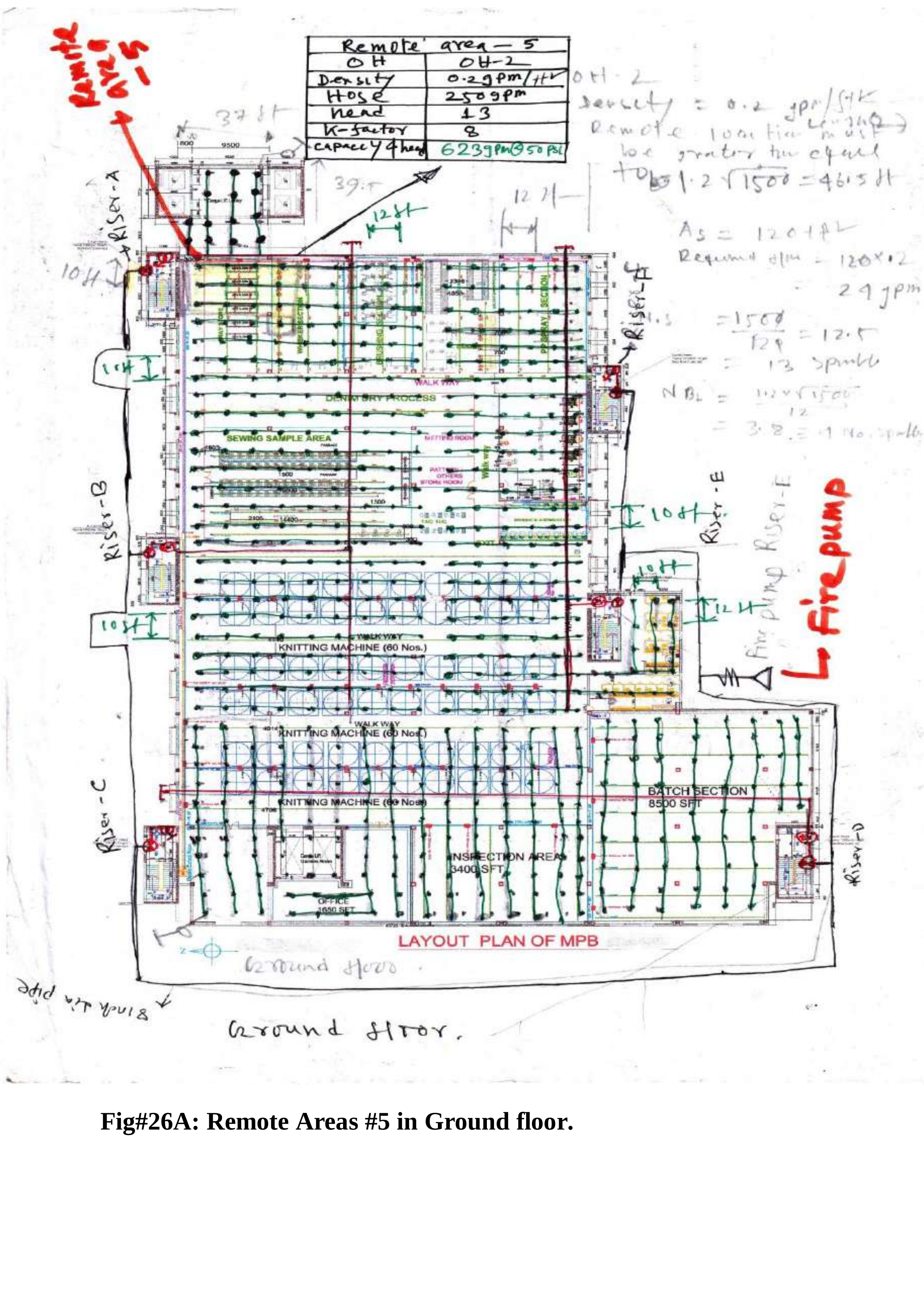
SYM	NAME	FINISH	TEMP	K(GPM/ psi½)	NPT	MFG	SIN	MODEL	Installed /Floor
	UPRIGHT	BRASS	155°F (68°C)	11.2	(3/4 in. NPT)	TYCO	TY5 131	ELO	2^{nd}, 3^{rd}, 4th & 5^{th} floors.
	UPRIGHT	BRASS	155°F (68°C)	8	(3/4 in. NPT)	TYCO	TY4 131	FRB	Ground floor.
	UPRIGHT	BRASS	155°F (68°C)	5.6	1/2 in. NPT	TYCO	TY3 131	FRB	1^{st} floor & Cargo lift lobbies of all floors.

5.3 Hydraulic Calculations:

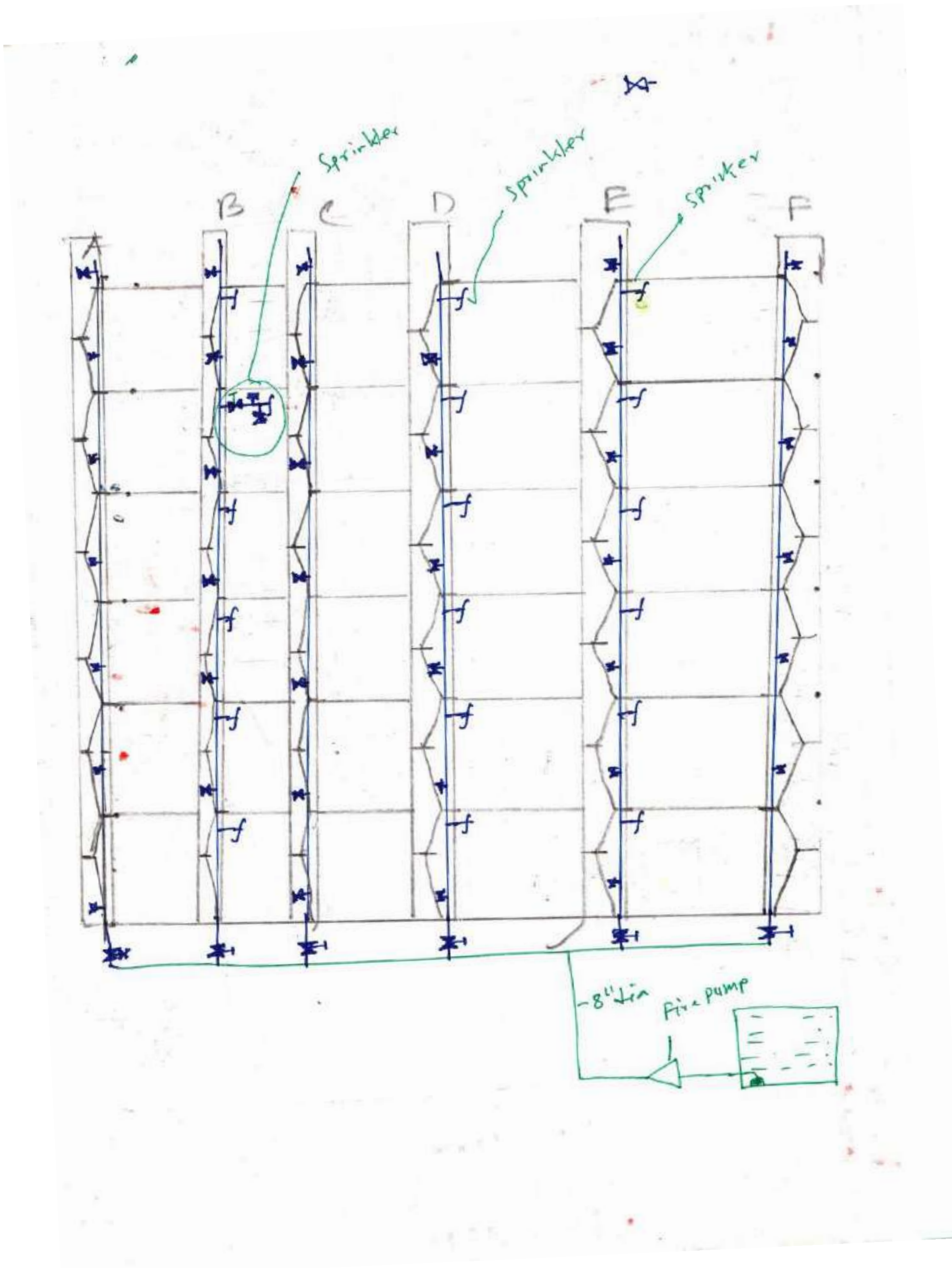
Hydraulic calculations were performed to determine the water demand (pressure and gpm) required at the discharge of the fire pump. According to Section 19.3.3.2.2.1 of NFPA 13, the minimum design area shall correspond with the hazard or the area protected by 13 sprinklers, whichever is greater. To ensure compliance with this requirement, three remote areas of the sprinkler system (5th floor away from the fire pump) were evaluated (see Fig#26 & 26A-B).



Fig#26: Remote Areas for Hydraulic Calculation at 5th floor.



Fig#26A: Remote Areas #5 in Ground floor.



Fig#26B: Riser Diagram of MPB building fire protection system.

Remote Area #1 is 1500 ft^2 consisting of thirteen sprinkler of 11.2 K-factor heads. Remote Area #2 & 3 are same as Area#1 but in located in different riser; however, Remote Area-4 & 5 are in First and ground floor having K factor of 5.6 and 8. Hand calculations were performed to determine the water demand.

In addition, Standpipe Hydraulic calculation also provided. NFPA14 governs the design and installation of standpipe system. A summary of standpipe system requirements set forth in NFPA 14 was are in Table 26.

Table26: of Standpipe System Requirements.

Standpipe Specifications			Reference
Size	Class I	At least 4 in.	14:7.6.1
Flow	500 gpm	2 most remote connections	14:7.6.3, &.10.1.1.1
Calculation	250 gpm	For each remote additional connection	14:7.10.1.2.1
	100 psi residual	All other standpipe	14:7.8.1

The inputs/ results for these calculations are shown in Table 27 & Table#28.

Remote Area #1 proved to have the largest system demand. This demand was graphed on hydraulic graph paper along with the water supply curves and the pump curve (see Fig#27 & 27A). This graph shows that as no city water supply is available in Bangladesh. So, this demand will easily meet by listed fire pump. A larger demand of 1000 gpm @ 172 psig is required for the standpipe system Hydraulic calculations are provided in Appendix-8 (see Appendix 8 for all calculation details).

Tabe27: Minimum K factor is provided in below table as per NFPA13.

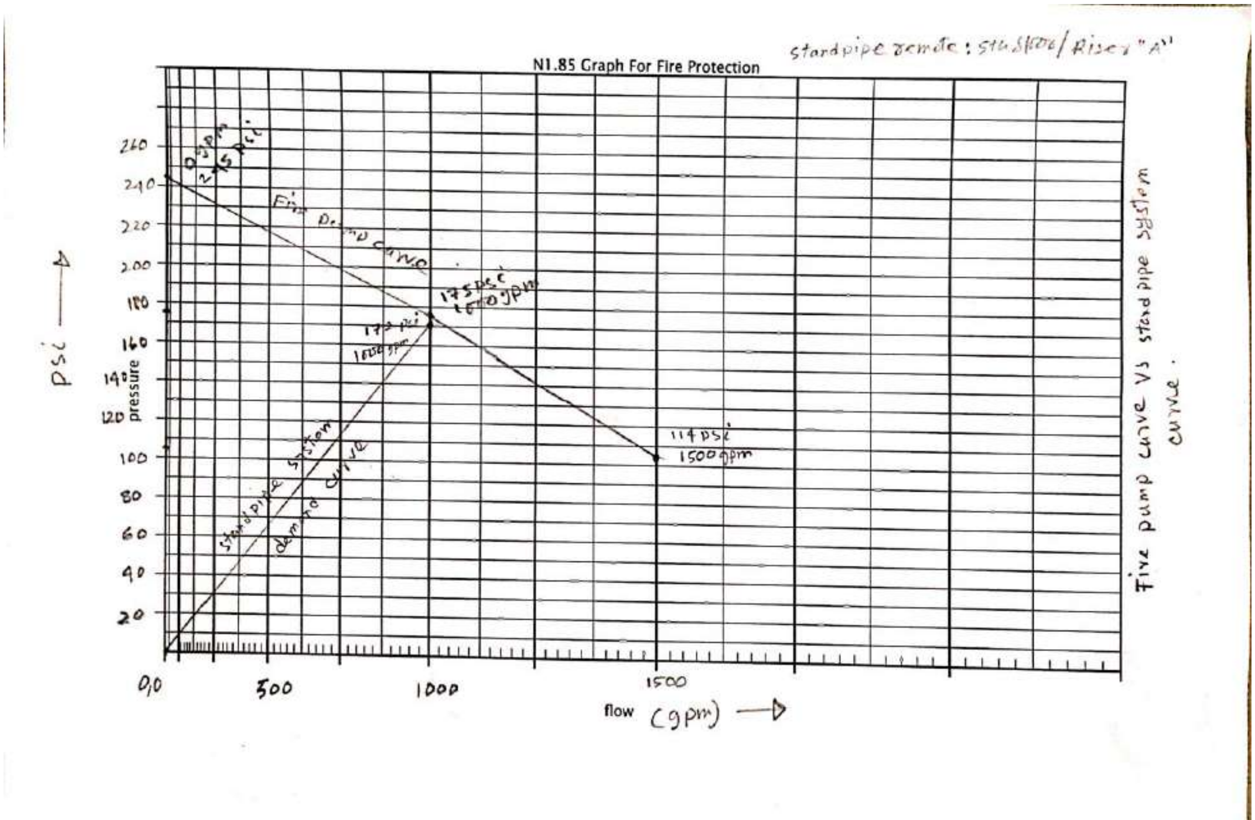
K-FACTOR SELECTOR

Coverage per Sprinkler	Density	Minimum Flow	K-Factor	Minimum Pressure by Code/Listing	Minimum Pressure to Meet Density	Actual Pressure Required	Actual Flow
(ft^2)	(gpm/ft^2)	(gpm)	(listing)	(psi)	(psi)	(psi)	(gpm)
130	0.20	26.0	2.8	7.0	86.2	86.2	26.0
			4.2	7.0	38.3	38.3	26.0
			4.9	7.0	28.2	28.2	26.0
			5.6	7.0	21.6	21.6	26.0
			8.0	7.0	10.6	10.6	26.0
			11.2	7.0	5.4	7.0	29.6
			14.0	7.0	3.4	7.0	37.0
			16.8	7.0	2.4	7.0	44.4
			22.4	7.0	1.3	7.0	59.3
			25.2	7.0	1.1	7.0	66.7
			User	7.0	-	-	-
			User	7.0	-	-	-
			User	7.0	-	-	-
			User	7.0	-	-	-

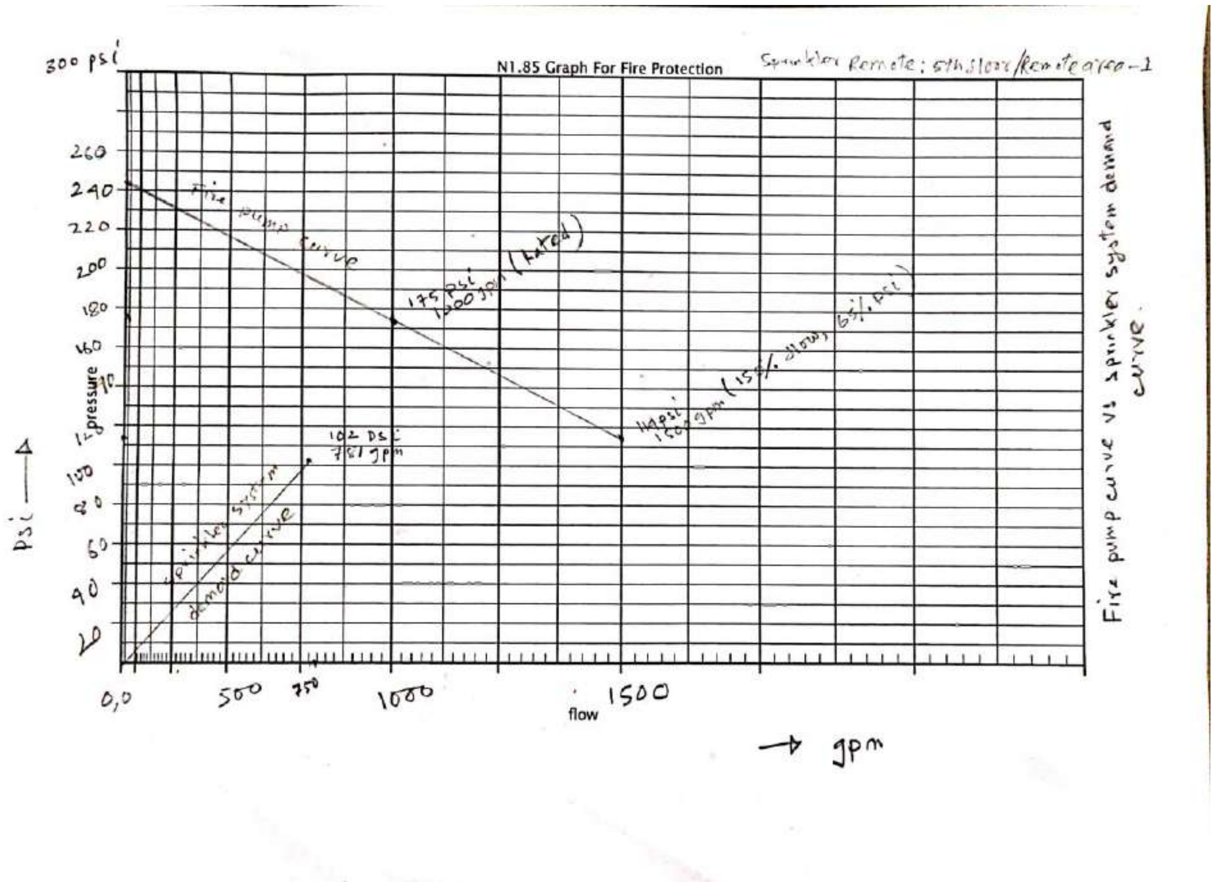
Table 28. Summary of Hand Hydraulic Calculations for MPB's Fire Suppression System

	Remote Area #1	Remote Area #2	Remote Area#3	Remote Area#4	Remote Area#5
Occupancy Classification	OH-2	OH-2	OH-2	OH-2	OH-2
Density	$0.2 gpm/ft^2$	$0.2 gpm/ft^2$	$0.2 gpm/ft^2$	$0.2 gpm/ft^2$	$0.2 gpm/ft^2$
Sprinkler Type	Upright	Upright	Upright	Upright	Upright
K-Factor	11.2	11.2	11.2	5.6	8
Minimum Sprinkler Flow	29.63 gpm	29.63 gpm	29.63 gpm	24 gpm	24 gpm
Minimum Sprinkler Pressure	7 psi	7 psi	7 psi	18.36 psi	9 psi
Number of Sprinklers Calculated	13	13	13	13	13
Hose	250 gpm	250 gpm	250 gpm	250 gpm	250 gpm
Hand calculation Demand	781 gpm @ 102 Psi	781 gpm @ 86 psi	781 gpm @ 88 psi	600gpm@58 psi	623 gpm @ 50 Psi

*Hand calculations were performed as if the system were designed as a branch system.



Fig#27: Standpipe system demand curve compared to pump curve.



Fig#27A: Sprinkler system demand curve compared to fire pump curve.

Earthquake Bracing (Sway Bracing) and Hangers:

The installation of sway bracing and hangers is addressed in Chapter 18 of NFPA 13. The specific paragraphs that address hanger and bracing requirements are reproduced below.

<u>Hangers</u>

Hangers are included in the sprinkler system design according to the requirements of Chapter 17 of NFPA 13.

These basic requirements include:

- Hangers are required to be designed to support five times the weight of the water-filled pipe plus 250 lb. (114 kg) at each point of piping support.
- Each point of support is required to be adequate to support the system.

- The maximum spacing between hangers is indicated in NFPA 13 Tables 17.4.2.1(a) or Table 17.4.2.1(b) – provided for reference below (See Table 29 & 29A).

Table 29 – Maximum Distance between Hangers

Table 17.4.2.1(a) Maximum Distance Between Hangers (ft-in.)

	Nominal Pipe Size (in.)											
	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8
Steel pipe except threaded lightwall	NA	12-0	12-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0	15-0
Threaded lightwall steel pipe	NA	12-0	12-0	12-0	12-0	12-0	12-0	NA	NA	NA	NA	NA
Copper tube	8-0	8-0	10-0	10-0	12-0	12-0	12-0	15-0	15-0	15-0	15-0	15-0
CPVC	5-6	6-0	6-6	7-0	8-0	9-0	10-0	NA	NA	NA	NA	NA
Ductile-iron pipe	NA	NA	NA	NA	NA	NA	15-0	NA	15-0	NA	15-0	15-0

NA: Not applicable.

Table 29A – Maximum Distance between Hangers

Table 17.4.2.1(b) Maximum Distance Between Hangers (m)

	Nominal Pipe Size (mm)											
	20	25	32	40	50	65	80	90	100	125	150	200
Steel pipe except threaded lightwall	NA	3.7	3.7	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Threaded lightwall steel pipe	NA	3.7	3.7	3.7	3.7	3.7	3.7	NA	NA	NA	NA	NA
Copper tube	2.4	2.4	3.0	3.0	3.7	3.7	3.7	4.6	4.6	4.6	4.6	4.6
CPVC	1.7	1.8	2.0	2.1	2.4	2.7	3.0	NA	NA	NA	NA	NA
Ductile-iron pipe	NA	NA	NA	NA	NA	NA	4.6	NA	4.6	NA	4.6	4.6

NA: Not applicable.

- Hanger components are required to be ferrous unless specifically permitted to be not listed as addressed by NFPA 13.
- Components of hanger assemblies that directly attach to the pipe or to the building structure shall be listed unless specifically permitted to be not listed by NFPA 13.
- Mild steel hangers formed from rods shall be permitted to be not listed.
- Fasteners shall be listed unless specifically permitted to be not listed as addressed by NFPA 13 for concrete, steel, and wood.
- Nonferrous components that have been proven by fire tests to be adequate for the hazard

application that are listed for a specific purpose and that are in compliance with the other requirements of NFPA 13.

- Holes through solid structural members are permitted to serve as hangers for the support of system piping provided such holes are permitted by applicable building codes and the spacing and support provisions for hangers of NFPA 13 are satisfied.
- A hanger is required on each section of branch line pipe. Starter lengths of branch line pipe less than 6 ft. in length do not require a hanger. Where sprinklers are spaced less than 6 ft. apart hangers spaced up to a maximum of 12 ft. is permitted on branch lines.
- A hanger is required on mains between every branch line connection, or on every section of pipe, unless hangers in these locations are permitted to be omitted due to other prescriptive hanger arrangements.

5.4 Earthquake Protection

The warehouse sprinkler system is protected from damage caused by an earthquake according to NFPA 13. Fire sprinkler systems are protected against earthquake damage by:

- Use of flexible joints and clearances in and around piping to minimize stresses that would develop due to differential building movement
- Use of bracing to ensure that sprinkler piping is maintained fairly rigid when supported by building elements so that the piping and building will move as a unit.

The following basic requirements for earthquake protection include:

- Listed flexible couplings are used in the design of sprinkler systems for flexibility during earthquakes. Systems having more flexible couplings than prescribed are required to have additional sway bracing installed.
- The use of flexible couplings for drops are prescribed by NFPA 13 regardless of pipe size.
- Seismic separation is required for fire sprinkler piping that crosses building seismic separation joints.
- Clearance is required to be provided around piping that extends through walls, floors, platforms, and foundations according to the prescriptive requirements of NFPA 13
- Lateral earthquake bracing is provided on all mains regardless of pipe size and on branch

line piping 2 ½” and larger.

- Lateral sway bracing is provided at a maximum interval of 40 ft.
- The distance between the last sway brace on a main is provided within 6 ft of the end of the pipe. The last length of pipe at the end of a feed or cross main is provided with a lateral sway brace.
- Longitudinal sway bracing is provided at a maximum interval of 80 ft.
- The distance between the last longitudinal sway brace and the end of the pipe does not exceed 40 ft.

5.5 Testing and Maintenance Requirements

Inspection, Testing and Maintenance Requirements:

A sprinkler system installed in accordance with this standard shall be properly inspected, tested, and maintained by the property owner or their authorized representative in accordance with NFPA 25 to provide at least the same level of performance and protection as designed according to 31.1, NFPA13,2019. A hydrostatic test will be required for the wet pipe system in MPB Building. Routine inspection and maintenance requirements are detailed in NFPA 25. Table 30 provides a summary of the system components that must be inspected, the frequency of inspection, and a reference to specific inspection requirements. The requirements are also shown in Table 31.

Table 30: Summary of sprinkler system inspection, testing, and maintenance.

Table 5.1.1.2 Summary of Sprinkler System Inspection, Testing, and Maintenance

Item	Frequency	Reference
Inspection		
Assessment of the internal piping condition		Chapter 14
Control valves		Chapter 13
Fire department connections		Chapter 13
Gauges (wet and deluge systems)		Chapter 13
Gauges (dry and preaction systems)		Chapter 13
Hanger/braces/supports	Annually	5.2.3
Heat tracing	Per manufacturer's requirements	5.2.6
Hydraulic design information sign	Annually	5.2.5
Information signs	Annually	5.2.7, 5.2.8, 5.2.9
Pipe and fittings	Annually	5.2.2
Sprinklers	Annually	5.2.1
Sprinklers (spare)	Annually	5.2.1.4
Supervisory signal devices (except valve supervisory switches)		5.2.4, Chapter 13
System valves		Chapter 13
Valve supervisory signal devices		5.2.4, Chapter 13
Waterflow alarm devices	Quarterly	5.2.4
Test		
Antifreeze solution	Annually	5.3.4
Control valves		Chapter 13
Gauges		Chapter 13
Main drain		Chapter 13
Sprinklers	At 50 years and every 10 years thereafter	5.3.1.1.1, 5.3.1.1.1.1, 5.3.1.1.1.2
Sprinklers	At 75 years and every 5 years thereafter	5.3.1.1.1.5
Sprinklers (dry)	15 years and every 10 years thereafter	5.3.1.1.1.6
Sprinklers (extra-high or greater temperature solder type)	5 years	5.3.1.1.1.4
Sprinklers (fast-response)	At 20 years and every 10 years thereafter	5.3.1.1.1.3
Sprinklers (harsh environments)	5 years	5.3.1.1.2
Supervisory signal devices (except valve supervisory switches)		Chapter 13
System valves		Chapter 13
Valve supervisory signal devices		Chapter 13
Waterflow alarm devices (mechanical)	Quarterly	5.3.3.1
Waterflow alarm devices (vane and pressure switch type)	Semiannually	5.3.3.2
Maintenance		
Low-point drains (dry pipe and preaction systems)		Chapter 13
Sprinklers and automatic spray nozzles protecting commercial cooking equipment and ventilation systems	Annually	5.4.1.7
Replacement of sprinklers	Removed for any reason	5.4.1.1
Valves (all types)		Chapter 13
Investigation		
Obstruction		Chapter 14

Table 31. Inspection, Testing and Maintenance Frequencies for Fire Suppression System Components

System Component	Description	Inspection	Testing	Maintenance
Pipe	ASTM A135, Type E Grade A (schedule 10) ASTM A795, Type E Grade A (schedule 40)	Annually	N/A	As Required
Fittings	ANVIL Couplings, Tees, Elbows & Drain Caps	Annually	N/A	As Required
Sprinklers	Tyco Standard Coverage Tyco Upriright Tyco Upright	Annually	At 20 years and every 10 years thereafter	As Required
Backflow Preventer	Colt C200 (8")	Weekly/ Monthly	Annually	As Required
Supervisory Switch	Potter OSYSU-1	Monthly	Semiannually	As Required
Valves	Control Valves: Mueller R-2360-6 Butterfly Valves: Gruvlok AN7722-3A Check Valves: Gruclok 78FP	Monthly (Locked) Weekly (Sealed) 5 years	Annually	Annually/ As Required
Hangers	ANVIL C-Clip & Swivel Ring	Annually	N/A	As Required
Fire Pump	Fairbanks Nijhuis Model 1800 Electric, Horizontal Split Case	See NFPA 25	See NFPA 25	See NFPA 25

Section Summary – Fire Suppression Systems:

The MPB building is fully equipped with a wet-pipe automatic sprinkler system primarily comprised of upright standard sprinklers. The sprinklers are appropriately located and water is supplied to this system via six standpipes located in each of the building's stairwells. A listed diesel driven firewater pump rated for 1000 gpm at 175 psi was installed to help meet the hydraulic demands of the sprinkler and standpipe system in accordance with NFPA 13 & NFPA 14. No deficiencies related to the fire suppression system were identified.

A properly designed fire suppression system should limit a fire's growth. However, occupants rely upon a building's egress system to remove themselves from potentially dangerous situations that may arise within a building. Hydraulic calculations are shown in Appendix -8.

Egress Design

6.1 Occupant Load and Exit Capacity Calculations:

The following section presents a summary of the key design features and system components related to egress analysis and design for this MPB building.

The first thing that can be observed when analyzing the egress design of this building is the identification of the exits.

The building has six stairways each with a door leading to the exterior. Stairway number-1 and stair number-2 are toward the front of the building near the electric room area and stairway number two is toward the opposite side of the building, leading to an exit discharge . There are two more exits, exit stair number-3 and exit stair-4 in the middle of the building opposite to each other. Exit stair number-5 and exit stair number-6 are rear side of the building, Exit stair number-5 is near by the shaft of the four elevators and stair number-6 is opposite to stair number five. All exit stairs must be remotely located. Dead end, common path and travel path also must meet the LSC and IBC.

All utility spaces (e.g., mechanical and electrical rooms) with in warehouse building are industrial use areas and are incidental to the predominant occupancy in the area in which they are located.

Common areas, such as restrooms, elevators, and stairwells are shared by all occupancies in the mixed occupancy warehouse building.

The following calculations are performed to verify one of the basic prescriptive requirements of egress systems: Exit Capacity > Occupant Load. For each floor of this storage building, the following requirements will be analyzed:

- The occupant load of each floor/space
- The exit capacity from each floor/space
- Verify that the exit capacities are adequate for each floor/space
- Verify that the arrangement of exits is appropriate

Occupant Load:

One of the first steps in evaluating the adequacy of a building's egress system is determining the building's occupant load by dividing a space's area by an occupant load factor. IBC defines occupant load as *the number of persons for which the means of egress of a building or portion thereof is designed. Occupant load has been calculated in MPB building and occupant load factor has been provided both from IBC, 2018 and NFPA 101, 2018.Calculating* occupant load can be thought of in three steps:

- Select an occupant load factor
- Determine the size of the room
- Apply the occupant load factor to the space

The occupant load in any building or portion thereof shall be not less than the number of persons determined by dividing the floor area assigned to that use by the occupant load factor for that use as specified in Table 7.3.1.2, Figure 7.3.1.2(a), and Figure 7.3.1.2(b). Where both gross and net area figures are given for the same occupancy, calculations shall be made by applying the gross area figure to the gross area of the portion of the building devoted to the use for which the gross area figure is specified and by applying the net area figure to the net area of the portion of the building devoted to the use for which the net area figure is specified (7.3.1.2, NFPA101, 2018, see Table 32).

Table 32: Occupant Load Factor.

Table 7.3.1.2 Occupant Load Factor

Use	(ft^2/person)[a]	(m^2/person)[a]
Assembly Use		
Concentrated use, without fixed seating	7 net	0.65 net
Less concentrated use, without fixed seating	15 net	1.4 net
Bench-type seating	1 person/18 linear in.	1 person/455 linear mm
Fixed seating	Use number of fixed seats	Use number of fixed seats
Waiting spaces	See 12.1.7.2 and 13.1.7.2.	See 12.1.7.2 and 13.1.7.2.
Kitchens	100	9.3
Library stack areas	100	9.3
Library reading rooms	50 net	4.6 net
Swimming pools	50 (water surface)	4.6 (water surface)
Swimming pool decks	30	2.8
Exercise rooms with equipment	50	4.6
Exercise rooms without equipment	15	1.4
Stages	15 net	1.4 net
Lighting and access catwalks, galleries, gridirons	100 net	9.3 net
Casinos and similar gaming areas	11	1
Skating rinks	50	4.6
Business Use (other than below)	150	14
Concentrated Business Use[f]	50	4.6
Airport traffic control tower observation levels	40	3.7
Collaboration rooms/spaces ≤450 ft^2 (41.8 m^2) in area[f]	30	2.8
Collaboration rooms/spaces >450 ft^2 (41.8 m^2) in area[f]	15	1.4
Day-Care Use	35 net	3.3 net
Detention and Correctional Use	120	11.1
Educational Use		
Classrooms	20 net	1.9 net
Shops, laboratories, vocational rooms	50 net	4.6 net
Health Care Use		
Inpatient treatment departments	240	22.3
Sleeping departments	120	11.1
Ambulatory health care	150	14
Industrial Use		
General and high hazard industrial	100	9.3
Special-purpose industrial	NA	NA
Mercantile Use		
Sales area on street floor[b,c]	30	2.8
Sales area on two or more street floors[c]	40	3.7
Sales area on floor below street floor[c]	30	2.8
Sales area on floors above street floor[c]	60	5.6
Floors or portions of floors used only for offices	See business use.	See business use.
Floors or portions of floors used only for storage, receiving, and shipping, and not open to general public	300	27.9
Mall structures[d]	Per factors applicable to use of space[e]	
Residential Use		
Hotels and dormitories	200	18.6
Apartment buildings	200	18.6
Board and care, large	200	18.6
Storage Use		
In storage occupancies	NA	NA
In mercantile occupancies	300	27.9
In other than storage and mercantile occupancies	500	46.5

NA: Not applicable. The occupant load is the maximum probable number of occupants present at any time.

As like NFPA, design of occupant load is calculated based on section 1004 of IBC, 2018. The number of occupant shall be computed at the rate of one occupant per unit area as prescribed in table 1004.5.

Occupancy plan of 5th floor are shown in Fig#28.

Fig#28:MPB Area Uses (5th Floor)

Table 33: MPB's Occupant Loads

Level	Function of Space	Area (sf)	Occupant Load Factor (sq. ft./occupant)	Calculated Occupant Load	Total Occupant Load
Gr. floor	Business	1850	100 gross	19	713
	Factory	68750	100 gross	688	
	Utility	1700	300 gross	6	
1	Business	3400	100 gross	34	712
	Factory	64900	100 gross	672	
	Utility	1700	300 gross	6	
2	Business	3400	100 gross	34	712
	Factory	64900	100 gross	672	
	Utility	1700	300 gross	6	
3	Storage	70600	300 gross	236	242
	Utility	1700	300 gross	6	
4	storage	70600	300 gross	236	242
	Utility	1700	300 gross	6	242
5	Storage	70600	300 gross	236	242
	Utility	1700	300 gross	6	
Total					**2863**

Table 33 shows the different uses/ space functions found on each level as well as their combined areas. These areas were divided by the occupant load factors prescribed by Section 1004 of the LSC to determine each space's occupant load. The occupant loads of each space were combined to determine each level's total occupant load. Ground floor has the highest total occupant load because of the large factory space located on this level.

6.2 Egress Capacity.

When a fire occurs within a building, it is vital that the occupants have an easily accessible egress point. These exits are strictly regulated, in every aspect, by the building code. The location, size and fire protection of the exit is vital to assuring people are able to get out of the building to safety. Calculating the capacity of a current exit is done by measuring its width and doing a calculation to understand how many occupants it can serve.

The method used by NFPA 101-the Life Safety Code to calculate egress capacity is the same, but egress capacity factor vary slightly from those of IBC.

As described by Section 7.3.1.1.1 of the LSC, *the total capacity of the means of egress for any story, balcony, tier or other occupied space shall be sufficient for the occupant load thereof*. Capacity is calculated by dividing the widths of means of egress elements by an appropriate capacity factor. The capacity of a means of egress is based on the capacity of its least efficient element. Since occupants are expected to transverse stairways at a slower speed than level components, stairways typically have a larger capacity factor (0.3"/ occupant) than level components (0.2"/ occupant).

However, the IBC allows the capacity factor for stairways to be reduced to (0.2"/ occupant) in buildings protected throughout by an approved sprinkler system and an emergency voice/ alarm communication system (Section 1005.3.1). The MPB meets both of these requirements.

6.3 Calculation of the exit capacity from each floor / space

7.3.3.1 Egress capacity for approved components of means of egress shall be based on the capacity factors shown in Table 34 as per 7.3.3.1 of NFPA 101, unless otherwise provided in 7.3.3.2.

7.3.3.2* For stairways wider than 44 in. (1120 mm) and subject to the 0.3 in. (7.6 mm) width per person capacity factor, the capacity shall be permitted to be increased using equation 7.3.3.2.

Table 34: Capacity Factors from NFPA101 Section 7.3.3.1

Table 7.3.3.1 Capacity Factors

	Stairways (width/person)		Level Components and Ramps (width/person)	
Area	**in.**	**mm**	**in.**	**mm**
Board and care	0.4	10	0.2	5
Health care, sprinklered	0.3	7.6	0.2	5
Health care, nonsprinklered	0.6	15	0.5	13
High hazard contents	0.7	18	0.4	10
All others	0.3	7.6	0.2	5

7.3.3.2* For stairways wider than 44 in. (1120 mm) and subject to the 0.3 in. (7.6 mm) width per person capacity factor, the capacity shall be permitted to be increased using the following equation:

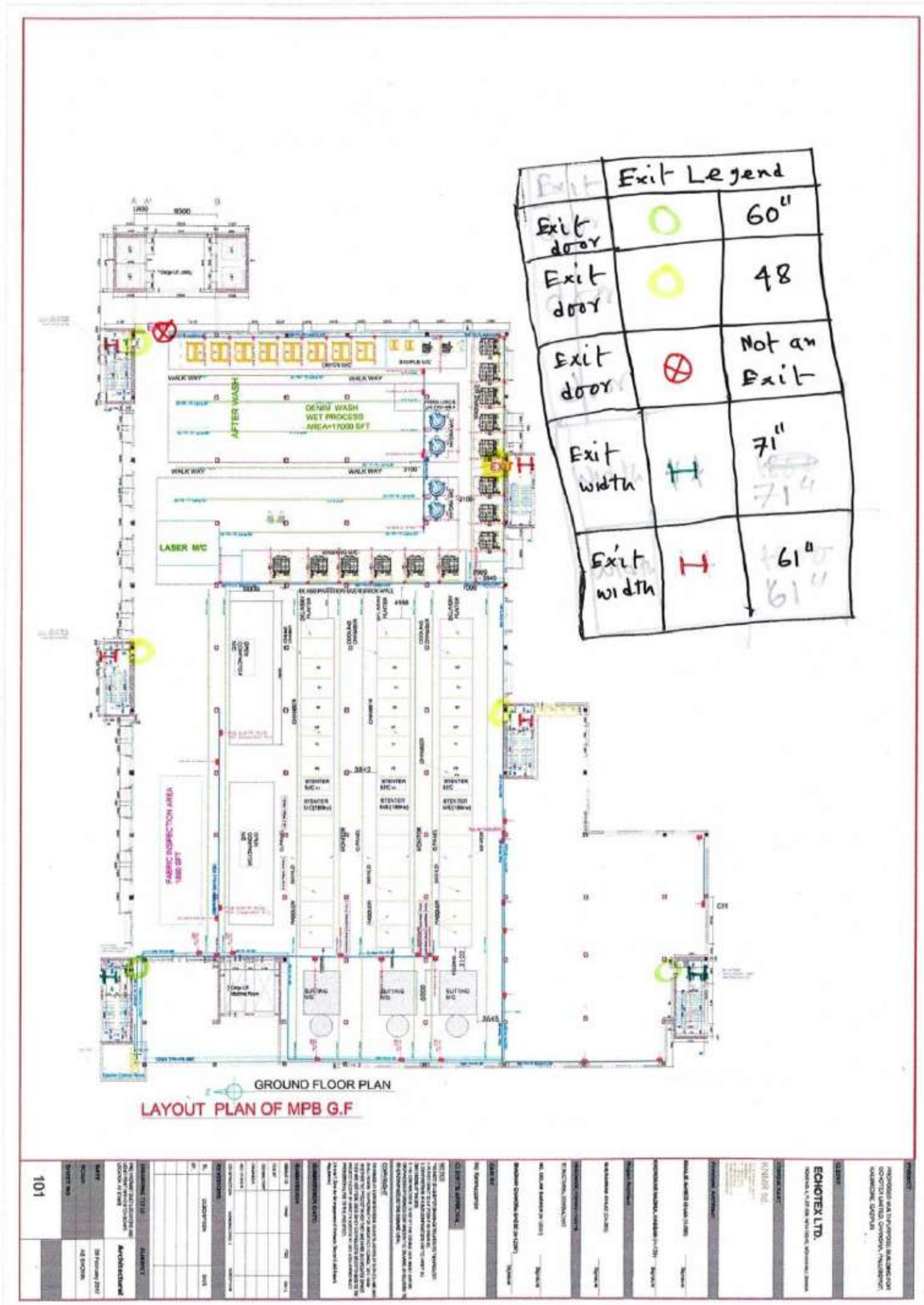
$$C = 146.7 + \left(\frac{Wn - 44}{0.218}\right) \qquad \textbf{[7.3.3.2]}$$

where:

C = capacity, in persons, rounded to the nearest integer

Wn = nominal width of the stair as permitted by 7.3.2.2 (in.)

The IBC requires the means of egress system for every story of a building to provide enough exits based on the aggregate occupant load of that floor. Table 35 summarizes the total capacity and total occupant load for each level of the MPB building. As this table displays, the total capacity of the Ground, first, second, third fourth & fifth floor exceed the occupant load. Ground floor Exit location and width of MPB building are shown in Fig#29.



Fig#29: MPB Building Exit Locations/ Width (First Floor)

Table #35: MPB Egress Capacity vs. Occupant Load Capacity.

Floor/Level	Door Factor inch/person	Stair Factor inch/person	Occupant Load (person)	Exit door Door capacity (person) inch	Stair Capacity (all exit width greater than 44 inch) Person
Ground	0.2	0.3	713	1653	1181
1	0.2	0.3	712	1653	1181
2	0.2	0.3	712	1653	1181
3	0.2	0.3	242	1653	1181
4	0.2	0.3	242	1653	1181
5	0.2	0.3	242	1653	1181

6.4 Number and Arrangement of Exits:

The building is classified as a mixed occupancy by the LSC. It is primarily classified as storage occupancy as three floors occupancy with storage.

The number of means of egress from any balcony, mezzanine, story, or portion thereof shall be not less than two, except under one of the following conditions from NFPA 101, section 7.4.1 :

(1)A single means of egress shall be permitted where permitted in Chapters 11 through 43 and

(2)A single means of egress shall be permitted for a mezzanine or balcony where the common path of travel limitations of Chapters 11 through 43 are met.

The number of means of egress from any story or portion thereof, other than for existing buildings as permitted in Chapters 11 through 43, shall be as follows (7.4.1.2):

1. (1)Occupant load more than 500 but not more than 1000 — not less than 3
2. (2)Occupant load more than 1000 — not less than 4

The IBC requires a minimum number of exits from spaces (Section 1006.2) as well as from stories (1006.3). These requirements are summarized in Table 1006.3.1 of the IBC (see Table 36).

Six exits are provided on the each floor of the MPB. Since six exits are provided, if any of the

MPB’s exits fails, it still meets the 50 percent capacity requirement. The numbers of exits based on occupant load are shown in Table 36.

Table32. Minimum Number of Exits Required Per Story

OCCUPANT PER STORY	MINIMUM NUMBER OF EXITS OR ACCESS TO EXITS FROM STORY
1-500	2
501-1000	3
More than 1000	4

6.5 Exit Remoteness

The corresponding LSC requirements for remoteness of exits are reproduced in accordance with 7.5.1.3.1 through 7.5.1.3.7.

Since the building is fitted with a supervised automatic sprinkler system exits must be separated by a distance of one-third of the maximum overall diagonal dimension of the building. The overall diagonal dimension of the building is approximately 448 ft. which translates to a minimum distance required of 117 ft. between exits to meet the LSC remoteness criteria. The test for remoteness of exits is met on all floors of the building. Where more than one exit, exit access, or exit discharge is required from a building or portion thereof, such exits, exit accesses, or exit discharges shall be remotely located from each other and be arranged to minimize the possibility that more than one has the potential to be blocked by any one fire or other emergency condition.

Section 1007 of the IBC places restrictions on how close together two exits can be. Where two exits are required, Section 1007.1.1 requires exits in a building equipped with an automatic sprinkler system to be placed a distance apart not less than one-third the length of the maximum overall diagonal dimension of the building or area to be served measured in a straight line between them.

Common Path of Travel:

The corresponding LSC requirements for common path of travel are reproduced in Table 37.

Common path of travel limitations for both a business, factory and storage occupancies is 100 ft with sprinkler. There are no areas or corridors within the construction warehouse with a common path of travel in excess of 100 ft.

The LSC criterion for common path of travel is met for the building. Maximum common path of travel is 75 ft.

Travel Distance to Exits:

The corresponding LSC requirements for travel distance to exits are reproduced in Table 37 below to NFPA101.

Since the warehouse is a mixed occupancy, the most restrictive requirements apply. The building is protected by a supervised automatic fire sprinkler system throughout. For storage occupancy an exit must be capable of being reached within 400 ft. and for business occupancy an exit must be capable of being reached within 300 ft. The most restrictive travel distance is 300 ft.

At least one exit is within 300 ft. of every point within the building. The construction warehouse meets the LSC travel distance requirements.

Dead End Corridors:

The corresponding LSC requirements for dead end corridors are reproduced in Table 37 below to NFPA101.The length of this dead end corridor is less than LSC criteria of 50 ft. and it is compliant with the LSC.

The IBC typically limits corridor's dead end lengths to 20 feet. However, an exception for buildings equipped throughout with an approved sprinkler system allows this distance to be increased to 50 feet for specific occupancies (Section 1020.4). This dead end distance comes close, but does not exceed the dead end distance permitted by the IBC.

Example: maximum dead end is 32 ft. The requirement of means of egress is shown on Table 37.

Moreover, Common path, Dead-end, Exit remoteness, signage and barrier of 5th floor
is shown in Fig#30 & 30A-B.

Table 37: Means of Egress Requirements

Parameter/Limitation	Storage Occupancy (Chapter 42)	Existing Business Occupancy (Chapter 39)	Industrial Occupancies (Chapter 40)	LSC Chapter 7 Requirement
Remoteness of Exits*	(42.2.1.1) Each required means of egress is required to be in accordance with the applicable portions of Chapter 7.	(39.2.1.1) All means of egress is required to be in accordance with Chapter 7.	(40.2.1) Each required means of egress shall be in accordance with the applicable portions of Chapter 7.	(7.5.1.3.3) Minimum separation distance between two exits shall not be less than 1/3 the length of the maximum overall diagonal dimension of the building for buildings equipped throughout by a supervised automatic sprinkler system.
Common Path of Travel	(42.2.5, Table-42.2.5) 100 ft. when protected throughout by an approved, supervised, automatic sprinkler system.	(39.2.5.3.1) 100 ft. on a story protected throughout by an approved automatic sprinkler system.	(40.2.5.1 100 ft. on a story protected throughout by an approved automatic sprinkler system.	--
Travel Distance to Exits*	(42.2.6, Table-42.2.6) 400 ft. when protected throughout by an approved, supervised automatic sprinkler system.	(39.2.6.3) 300 ft. when protected throughout by an approved, supervised automatic sprinkler system.	(40.2.6.1) 400 ft. when protected throughout by an approved, supervised automatic sprinkler system.	--
Dead End Travel	(42.2.5, Table-42.2.5) 100 ft. when protected throughout by an approved, supervised, automatic sprinkler system.	(39.2.5.2) Dead-end corridors shall not exceed 50 ft	(40.2.5.1)50 ft.when protected throughout by an approved, supervised, automatic sprinkler system	(7.5.1.5) No dead end corridors unless permitted by occupancy chapter.

* The building is assumed to be protected throughout by an approved automatic fire sprinkler system.

Other Requirements for Egress Systems

6.6 Horizontal Exits

There are no horizontal exits in the warehouse building.

Elevator:

The construction warehouse elevator is not a designated means of egress.

6.7 Door swing and arrangement:

A door in a means of egress should be side-hinged or pivoted-swinging. Doors must swing in the direction of exit travel when:

1. Serving a room or area with an occupant load of 50 or more.
2. Used in an exit enclosure or where serving a high hazard area.

Again, there are exceptions depending upon the NFPA 101 occupancy classification. During its swing, the door should leave at least one-half the required width of an aisle, corridor, or landing available for use. For existing buildings, the minimum available space while the door is swinging is 22 inches. The door should not project more than 7 inches into the required width of an aisle or landing when fully opened. Both LSC (7.2.1.4.3) and IBC (1024.5) have the same requirements described above.

6.8 Locks:

Doors must be arranged to be readily opened from the exit side whenever the building is occupied. Also, a latch or other fastening device on a door must be provided with a knob, panic bar, or other simple type of releasing device having an obvious method of operation under all lighting conditions. Panic hardware and fire exit hardware consist of bars that must extend across not less than one-half the width of the door leaf, not less than 30 inches or more than 44 inches above the floor. An applied force not to exceed 15 pounds will cause the door latch to release. There are specific requirements for electronically controlled egress doors. Only approved fire exit hardware should be used on fire doors.

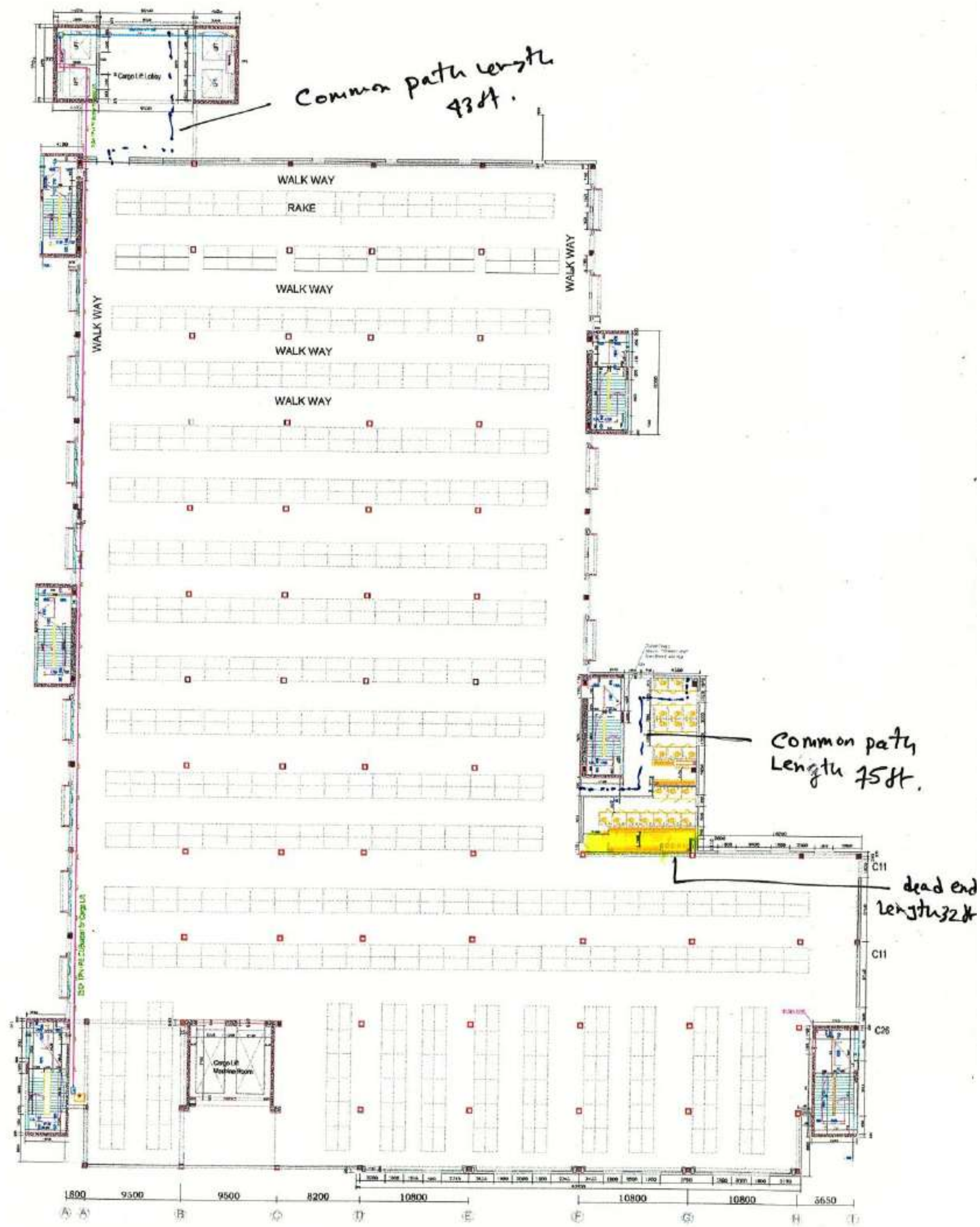
6.9 Marking means of egress:

All exits and access ways must be marked by an approved sign readily visible from any direction of exit access. Every sign must be so located and of such size, distinctive color, and design as to be readily visible and must provide contrast with decorations, interior finish, or other signs. Every sign must be suitably illuminated by a reliable light source. Externally and internally illuminated signs must be visible in both normal and emergency lighting mode.

6.10 Emergency lighting:

In buildings where artificial lighting is provided for normal use and occupancy, exit lighting and the illumination of the means of egress is required to ensure occupants can quickly evacuate the building. Emergency lighting (1-foot candle average; 0.01-foot candle minimum) must be provided for a period of 1.5 hours in the event of failure of normal lighting. The emergency lighting system must be arranged to provide the required illumination automatically in the event of any interruption (10 seconds) of normal lighting, such as any failure of public utility or other outside electrical power supply or opening of a circuit breaker or fuse. Either the emergency lighting system must be continuously in operation or capable of repeated automatic operation without manual intervention. All emergency lighting must be installed and tested in accordance with NFPA 111 (Full 1.5 hour test annually and 30-second test every 30 days.).

See Appendix -4 for building occupancy, Appendix-5 for Exit Location & Sizes and Appendix -6 for exit Separation Distances and appendix-9 for Common Path and dead-end.



5TH FLOOR PLAN

FINISHED FABRIC /HANGER/CARTON STORE (capacity=2500 ton)

Fig#30: Common Path and Dead End Lengths (5th Floor)

Fig#30A: Exit Separation in 5th floor.

Fig#30B: Fire Rated Barriers & Exit Signage (5th Floor)

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Section Summary – Egress

In short, a building's egress system is essentially the path occupants may use to exit a building safely. The majority of the building's egress system was found to comply with the LSC. A sufficient number of exits are provided. These exits are appropriately separated to reduce the probability of a single event rendering multiple exits unusable. No issues related to common path of travel or dead end distances were identified. However, the second floor's actual occupant load of 1000 persons exceed for this floor's total occupant load capacity of 712 persons. This issue can be solved reducing 1000 persons to 712 persons to meet floor's total occupant load capacity.

6.13 Emergency Planning and Preparedness

A Fire Safety Management Plan has been developed to inform occupants of their roles and actions to take in the event of a fire to ensure the safety of building occupants (see Appendix 11). The primary objective of this plan is to prevent injuries to its employees, contractors and visitors. It is the duty of all employees, contractors and occupants to review this plan and understand their roles and actions to take during an emergency.

In addition, the Fire Safety Management Plan outlines the following training requirements:

- All building occupants must be provided a copy and trained annually on the building Fire Safety Management Plan. New occupants must receive this information within 14 days of occupying the building.
- Floor Wardens must receive training at least annually. New Floor Wardens must receive training shortly after being appointed.
- Building occupants must attend regularly scheduled meetings/drills to ensure their proficiency during an emergency. This should include training on Floor Warden Procedures to enable them to assist occupants in the event that Floor Wardens are not available during an emergency.

Performance-Based Analysis

7.1 Performance-Based Analysis

This analysis is a performance-based evaluation of the fire protection features of the MPB Building. The objective of this analysis is to determine whether building occupants are exposed to an unreasonable level of risk in the event of a fire. This report will outline two design fire scenarios that are based on two of the fire scenarios suggested in NFPA 101. The selected design fire scenarios represent two scenarios that will present a significant challenge to the life safety features of the building.

Specific performance criteria related to visibility, temperature and carbon monoxide were set to determine if a specific fire scenario might create conditions that could adversely affect an occupant's ability to evacuate safely. An evaluation of the Available Safe Egress Time (ASET) versus the Required Safe Egress Time (RSET) or escape time was conducted for two different fire performance scenarios to determine if the performance objectives could be achieved (See Fig#31, FIGURE 3.11.4 of fire protection handbook).

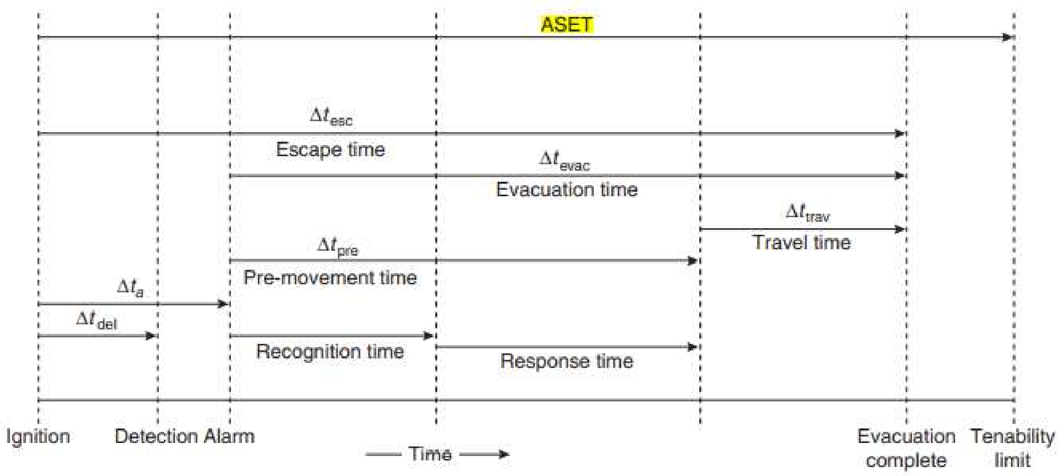


FIGURE 3.11.4 Example Time Line for Evaluation of Available Versus Required Safe Egress Times (Source: *Fire Safety Engineering in Buildings, Part 1: Guide to the Application of Fire Safety Engineering Principles,* Document DD240, BSI, 1997, Figure 2. Permission to reproduce extracts of DD240-1: 1997(E) is granted by BSI. British Standards can be obtained from BSI Customer Services, 389 Chiswick High Road, London W4 4AL. Tel: +44 (0)20 8996 9001. E-mail: cservices@bsi-global.com.)

Fig#31: ASET VS RSET model

7.2 Required Safe Egress Time (RSET) Analysis

The Required Safe Egress Time is the predicted time necessary to evacuate a building or component. The RSET can be subdivided into a number of discrete time intervals, the sum of which constitute the total RSET (SFPE Handbook, 2008, Section 3):

Where,

Δtd = time from fire ignition to detection (detection phase.)

Δta = time from detection to notification of occupants of a fire emergency (notification phase).

$\Delta tpre$ = time from notification (or cue reception) until evacuation commences (pre-evacuation phase).

Δ evac = time from the start of purposive evacuation movement until safety is reached (evacuation phase).

$\Delta tesc$=RSET, the required safe egress time is the time from ignition until the building or location of interest has been evacuated.

7.3 Detection and Notification Phase

The detection phase (Δtd) is the time from the fire ignition to detection of the fire. The notification phase (Δta) is the time from ignition to the time occupants become aware of the fire and the necessity to evacuate. Detection is assumed to occur once occupants become visually aware of smoke/ fire or when smoke detectors, sprinklers, or manual alarms activate the building's fire alarm. Occupants in close proximity to the fire can also be alerted by additional fire-induced conditions, such as smells and heat.

7.4 Pre-evacuation Phase

The pre-evacuation Phase ($\Delta tpre$) or pre-movement time indicate the time after a fire is discovered or an alarm is activated until occupants begin to evacuate. It is essentially the time occupants apply engaging in activities after they have been notified prior to actually evacuating the area. Illustrations of these activities comprise assessing the danger, gathering belongings, safeguarding critical materials, alerting others, etc. A wide variety of factors such as the occupant characteristics as well as how one becomes aware of a situation and how the threat is perceived will affect pre-movement times.

Based on the information of Table#38 (reference Table 3.3 of C/VM2 Verification Method: Framework for fire safety design | Amendment 4) and Fig#32 (Reference Figure 4.2.1 of Fire Protection Handbook), it is assumed the pre-movement time for the MPB building is between thirty seconds to one minute (depending on specific event scenario).

Table #38: Pre-travel activity times.

Table 3.3 **Pre-travel activity times**

Errata 1 Apr 2012

Description of *building* use	Pre-travel activity time(s)
Buildings **where the occupants are considered awake, alert and familiar with the *building* (eg, offices, warehouses not open to the public)**	
Enclosure of origin	30
Remote from the enclosure of origin	60
Buildings **where the occupants are considered awake, alert and unfamiliar with the *building* (eg, retail shops, exhibition spaces, restaurants)**	
Enclosure of origin (standard alarm signal)	60
Remote from the enclosure of origin (standard alarm signal)	120
Enclosure of origin (voice alarm signal)	30
Remote from the enclosure of origin (voice alarm signal)	60
Buildings **where the occupants are considered sleeping and familiar with the *building* (eg, apartments)**	
Enclosure of origin (standard alarm signal)	60
Remote from the enclosure of origin (standard alarm signal)	300
Buildings **where the occupants are considered sleeping and unfamiliar with the *building* (eg, hotels and motels)**	
Enclosure of origin	60
Remote from the enclosure of origin (standard alarm signal)	600
Remote from the enclosure of origin (voice alarm signal)	300
Buildings **where the occupants are considered awake and under the care of trained staff (eg, day care, dental office, clinic)**	
Enclosure of origin (independent of alarm signal)	60
Remote from the enclosure of origin (independent of alarm signal)	120

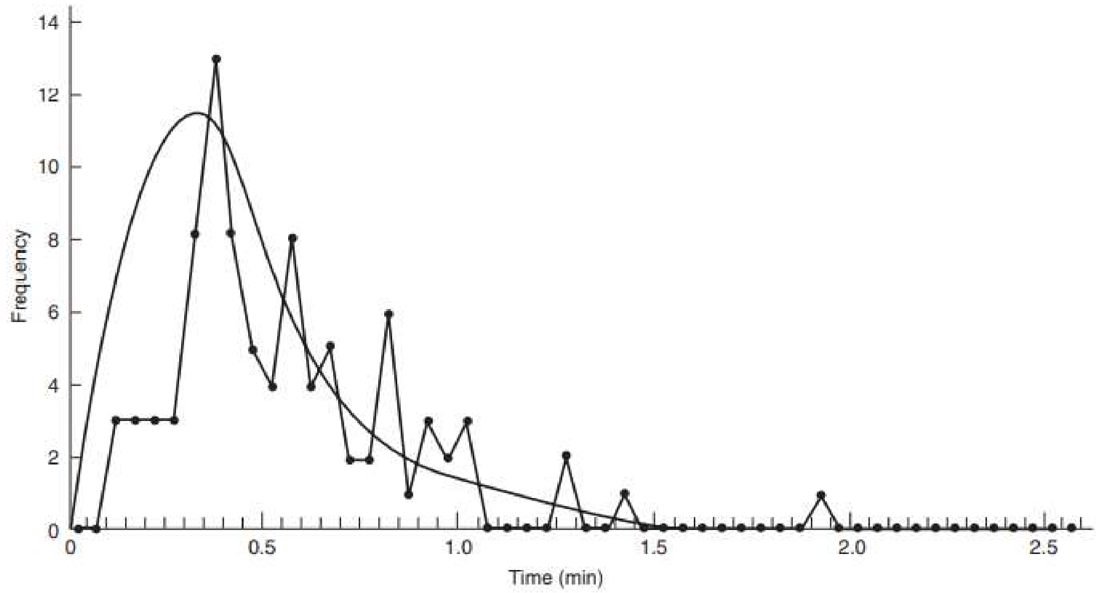


FIGURE 4.2.1 Experimental and Theoretical Premovement Times in a Department Store Evacuation

Fig#32: Experimental and Theoretical Premovement Times in a Department Store Evacuation.

7.5 Occupant Characteristics

The amount of time it takes occupants to safely exit a building will be affected by the characteristics of those occupants. The designer must consider the characteristics of a population that accurately reflects the expected user population. Characteristics such as an occupant's age, mobility, familiarity with the space, cognitive ability, etc. can have significant impacts on evacuation times. The MPB has three uses, warehouse/storage, factory /industrial, and business occupancy. Based on these uses, general assumptions relating to occupancy characteristics can be made.

For example, occupants using a space in a business capacity are likely to be familiar with the surroundings. Offices will typically have a low occupant density like the warehouse or storage occupancy. On the other hand, occupants using a space as a motel are less likely to be familiar with the surroundings. Average walking speed varies based on characteristics of the occupant which are providing in below (Table 4.2.2 outlined from Fire Protection Handbook) Table 39.

Table 39: Average walking speed based on occupant charterstics.

TABLE 4.2.2 Average Walking Speeds and Standard Deviation for Various Categories of Users of Two Shopping Centers[31]

User Category	Average Walking Speed (m/sec)	Standard Deviation (m/sec)	N
Adult with difficulty walking			
Older adult walking very slowly	0.83	0.20	21
Adult with walking disability	0.78	0.19	8
Pregnant woman	0.79	0.12	4
Adult with child, baby, or toddler	0.93	0.33	171
Adult with child and baby or toddler	0.88	0.26	25
Adult with baby or toddler	0.90	0.24	77
Adult with child	1.00	0.41	69
Older adult	0.93	0.22	155
Older adult with another person	0.88	0.23	49
Older adult walking alone	0.96	0.22	103
Able-bodied adult			
Walking with another person	0.93	0.25	314
Walking alone	1.14	0.27	446
Total	1.03	0.29	937

Source: Interscience Communications

Some of the following assumptions have been made regarding the MPB's occupants:

- Majority of occupants are between 19 – 55 years old;
- Majority of occupants are fully mobile;
- Majority of occupants are familiar with the building;
- Majority of occupants are trained in evacuating the building (regular drills conducted);
- Majority of occupants will follow the instructions of trained floor wardens;
- Occupants are conscious and unimpaired; and,
- Occupants will not resist instructions to evacuate the building (short delay time).

7.8 Evacuation Phase

The evacuation phase (Δtevac) or movement time is the time from the start of evacuation until occupants reach a safe location. Movement time is based upon the widths of stairs/ exit doors, the number of occupants using each exit, travel distance to exits, and occupant movement speed. Flow calculations described in the SFPE Handbook were used to determine the movement time associated with the two performance test scenarios described in Section 7.12 of this report. When applicable, the following assumptions were made:

- A relatively equal amount of occupants will use each stairwell;
- First floor occupants do not exit through the stairway;
- None of the occupants have disabilities that would significantly reduce their rate of travel;
- Occupants on lower floors will not be able to enter stairwells until upper levels have cleared;
- Maximum Specific Flow (F_{sm}) for stairwells = 18.5 persons/min/ ft. of effective width;
- Maximum Specific Flow (F_{sm}) for doors = 24.0 persons/min/ ft. of effective width; and,
- Average unimpeded travel speed = 265 feet/ min.
- Industrial buildings = 25–30 m/min (0.42–0.56 m/sec) max 2.33 m/sec

Travel speed based on density and occupancy has been provided in below table of Fire Protection Handbook (See Table 40).

Table# 40: Travel Speeds Based on Different Categories

TABLE 4.2.3 Travel Speeds Reported in the Referenced Literature

Type of Situation	*Measured Travel Speeds*				
A. Where Density Was Reportedly Not a Factor					
Transport terminals[31]	265 ft/min on walkways (1.35 m/sec)				
Average under "normal conditions"[33]	60 m/min (1.0 m/sec)				
Experiment with disabled subjects[24]					
	Min	1st Q	3rd Q	Max	Mean
On horizontal (m/sec)					
All disabled subjects	0.10	0.71	1.28	1.77	1.00
With locomotion disability	0.10	0.57	1.02	1.68	0.80
No aid	0.24	0.70	1.02	1.68	0.95
Crutches	0.63	0.67	1.24	1.35	0.94
Cane	0.26	0.49	1.08	1.60	0.81
Walker/rollator	0.10	0.34	0.83	1.02	0.57
Without locomotion disability	0.82	1.05	1.34	1.77	1.25
Unassisted wheelchair	0.85	—	—	0.93	0.89
Assisted ambulant	0.21	0.58	0.92	1.40	0.78
Assisted wheelchair	0.84	1.02	1.59	1.98	1.30
On upward incline					
All disabled	0.21	0.42	0.74	1.32	0.62
With locomotion disability	0.21	0.42	0.72	1.08	0.59
No aid	0.30	0.48	0.87	1.08	0.68
Crutches	0.35	—	—	0.53	0.46
Cane	0.21	0.38	0.70	1.05	0.52
Walker/rollator	0.30	—	—	0.42	0.35
Without locomotion disability	0.70	—	—	1.32	1.01
Unassisted wheelchair	0.70	—	—	—	—
Assisted ambulant	0.23	0.42	0.70	0.72	0.53
Assisted wheelchair	0.53	0.70	1.05	1.05	0.89
On downward incline					
All disabled	0.10	0.42	0.70	1.83	0.60
With locomotion disability	0.10	0.42	0.70	1.22	0.58
No aid	0.28	0.45	0.94	1.22	0.68
Crutches	0.42	—	—	0.53	0.47
Cane	0.18	0.35	0.70	1.04	0.51
Walker/rollator	0.10	—	—	0.52	0.36
Without locomotion disability	0.70	—	—	1.83	1.26
Unassisted wheelchair	1.05	—	—	—	—
Assisted ambulant	0.42	0.52	0.86	1.05	0.69
Assisted wheelchair	0.70	0.96	1.05	1.05	0.96
Mid-rise apartment drill[24]	0.47 m/sec on stairs (ranged from 0.34 to 1.08 m/sec among various adult age groups; one visually impaired person traveled 0.31 m/sec)				
Mid-rise apartment drill[24]	0.44 m/sec on stairs (ranged from 0.32 to 0.56 m/sec among various adult age groups)				
Mid-rise apartment drill[24]	0.41 m/sec on stairs (ranged from 0.30 to 0.47 among various adult age groups)				
High-rise apartment drill[23]	1.05 m/sec (ranged from 0.57 to 1.20 m/sec among various adult age groups)				
High-rise apartment drill[23]	0.95 m/sec (ranged from 0.56 to 1.12 m/sec among various adult age groups)				
B. Where Density Was a Factor					
Public places[32]	100–250 ft/min on walkways (0.51–1.27 m/sec) 70–150 ft/min on stairs (0.36–0.76 m/sec)				
Public places[33]	17 m/min minimum on horizontal (0.28 m/sec) 11–16 m/min down stairs (0.18–0.27 m/sec)				
Theaters and educational[33]	15–20 m/min (0.25–0.33 m/sec) max 2.33 m/sec				
Industrial buildings[33]	25–30 m/min (0.42–0.56 m/sec) max 2.33 m/sec				
Transport terminals[33]	20–25 m/min (0.33–0.83 m/sec) max 2.10 m/sec				
Descending stairs[33]	20–25 m/min (0.33–0.42 m/sec) max 1.28 m/sec				

7.9 Available Safe Egress Time (ASET) Analysis

The evaluation of the Available Safe Egress Time (ASET) is essential for organizing people evacuation in case of fire in industrial premises, buildings or generic enclosures. The Available Safe Egress Time (ASET) is the amount of time that elapses between fire ignition and the development of untenable conditions. ASET is determined by applying empirical correlations or fire modeling. First, a design fire (heat release rate history) is established by considering the types of combustibles present and their associated product yields (primarily soot and carbon monoxide). Next, this design fire is provided as input to a calculation tool such as a fire model to determine the time after ignition at which space through which occupants must pass becomes untenable due to the presence of smoke or heat. The time at which conditions become untenable (ASET) is the time at which the amount of smoke or heat, as calculated by a fire model or similar tool, first exceeds pre-established tenability criteria.

7.10 Tenability Criteria

In the event of a building fire, the occupants may be exposed to the fire and smoke. Statistical evidence shows that most fire deaths are not caused by direct contact with the fire, but by smoke inhalation. While a fire may be confined to a localized area in a building, the smoke produced will rise, forming a hot upper layer and may spread rapidly through the building. Exposure to toxic gases or heat may cause incapacitation (loss of consciousness); and severe exposure may cause death.

Tenability criteria defines specific parameters which if exceeded may expose occupants to untenable conditions. A number of different tenability criteria can be used in a performance design. However, this analysis will focus on visibility, temperature and carbon monoxide (thermal heat flux was also evaluated for one test scenario). These tenability limits will be evaluated at a height six feet above the finished floor level. The tenability limits discussed below are summarized in Table 41.

Table 41: MPB Building Tenability Criteria

Design Criteria	Tenability Limit	Reference
Visibility	10 meters	SFPE Handbook (pg-2-187)
Temperature	60^0C	SFPE Handbook (pg-2-222).
Carbon Monoxide	30,000 ppm*min	LSC (A.7.2.12.3.2)

As suggested in the SFPE Handbook for large enclosures, a visibility limit of 10 meters will be set for the MPB building. Visibility/ smoke obscuration can prevent or reduce the speed with which an occupant moves. Occupants typically will not use an escape route if the visibility is less than 3 meters. At a visibility of 5 meters, people often move as if in darkness.

Temperature can also pose tenability issues. The moisture released as a byproduct of combustion can reach temperatures in excess of 100°C. At this point, the steam/ saturated air will release large amounts of heat to an occupant's skin or if inhaled. Occupants can only breathe saturated air above 60°C for a few minutes before thermal burns will occur to an occupant's respiratory tract [8]. A temperature limit of 60°C will be set for the MPB building.

The majority of fire deaths are caused by carbon monoxide poisoning. Carbon monoxide is the most common toxic gas released in building fires. It can prevent evacuation by causing disorientation and loss of consciousness. The LSC discusses a tenability limit of 30,000 ppm*min for carbon monoxide in areas of refuge (A.7.2.12.3.2). A carbon monoxide limit of 30,000 ppm*min (integrated dose of 1,000 ppm for 30 minutes) will be set for the MPB building.

7.11 Life Safety Code Design Fire Scenarios

The Life Safety Code (NFPA 101) provides eight design fire (DF) scenarios that should be considered in the development of a performance-based design. Briefly, these design fire scenarios are as follows:

1. An occupancy-specific design fire scenario that is representative of a typical fire for the occupancy.

2. An ultrafast-developing fire in the primary means of egress, with interior doors open at the start of the fire (for a discussion of fire development, see Section 2, Chapter 4, "Dynamics of Compartment Fire Growth").

3. A fire that starts in a normally unoccupied room that may endanger large numbers of occupants.

4. A fire that originates in a concealed wall or ceiling space adjacent to a large occupied room.

5. A slowly developing fire, shielded from fire protection systems, in close proximity to a high-

occupancy area.

6. The most severe fire resulting from the largest possible fuel load characteristic of the normal operation of the building.

7. An outside exposure fire.

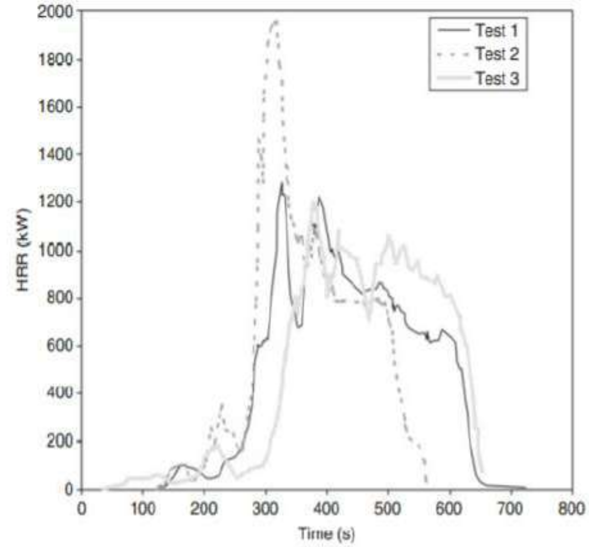
8. A fire originating in ordinary combustibles with each passive or active fire protection system individually rendered ineffective; this scenario is not required where it can be shown that the level of reliability and the design performance in the absence of the system are acceptable to the authority having jurisdiction (AHJ). Although only eight scenarios are listed in the LSC DF, one performance test deriving from LSC DF Scenario 6 and 8 was evaluated. This fire scenario 6 was selected because MPB building has rack storage on three floors and it can result in a fast developing fire. LSC DF Scenario 6 is selected because 3rd, 4th and 5th floor have rack storage throughout the floors. So, Fig#33 shows HRR of rack storage of cotton made men's suits.

On the other hand, this fire scenario 8 was selected because MPB building has an office room near the front elevator on the 1st floor and it can result in a medium developing fire. It was analyzed assuming detection system and passive fire protection system had failed.

7.12 Performance Test Scenarios:

Three different performance test scenarios were evaluated. All performance test scenarios used the same Heat Release Rate (HRR) curve. Data for the HRR curve was based on results, published in the SFPE Handbook, from a Japanese tests result on HRR of racks of men's suits where rack is 1.8 m long. Three tests were conducted. The HRR of worst-case scenarios is close to 2000 KW (See Fig#33, Test 2 of Fig.26.24 of SFPE Handbook).

Fig. 26.24 HRR of racks of men's suits; the rack was 1.8 m long (arranged as two rows side-by-side)



Fig#33: HRR of rack storage of cotton made suits.

It is assumed that real fires are rarely 2-D in shape. Items like upholstered furniture, wardrobes, workstations, and rack storage are clearly not 2-D fires, which are 3-D fire.

Engineers typically assume that a fire is simply a 2-D rectangular surface. This greatly simplifies the analysis and is often considered a reasonable assumption given all of the other uncertainties that exist with fire modeling. Combustion product yields from cotton fire are assumed to be carbon dioxide, carbon monoxide, acrolein & formaldehyde. Cotton fabric with formula (C6H8O4) is used in FDS.

From New Zealand, guidance for HRRPUA is currently given within C/VM2 Verification Method:

Non-storage occupancies 500 kW/m^2 <= HRRPUA >=1000 kW/m^2
Storage occupancies 1000 kW/m^2 <= HRRPUA >=2500 kW/m^2.

Other than in storage-type occupancies, it is assumed that a fire will grow horizontally and the HRRPUA will be more 2-D in nature than 3-D. This assumption is consistent with the widely used αt^2 that assumes that a fire grows in a circular shape at constant flame spread rate which leads to the t^2 dependence. Thus a HRRPUA >=500 kW/m^2 for non-storage occupancies represents a pragmatic lower limit.

Most accidental fires in buildings are considered to be buoyancy-driven fires, and therefore typical fire engineering analysis Q* should be limited to Q* < 2.5. (42.2 of Fire Science and Technology 2015).

Using typical values for the properties of air $\rho_a = 1.2$ kg/ n^3, $c_p = 1.01$ kJ/kg K, $T_a = 293$ K, and $g = 9.81$ m/s^2 and :ombining Eqs. 42.4 and 42.5 gives:

$$Q^* = \frac{\dot{Q}}{1112 D^{5/2}} < 2.5 \Rightarrow \dot{Q}'' < 725 \dot{Q}^{1/5} \qquad (42.6)$$

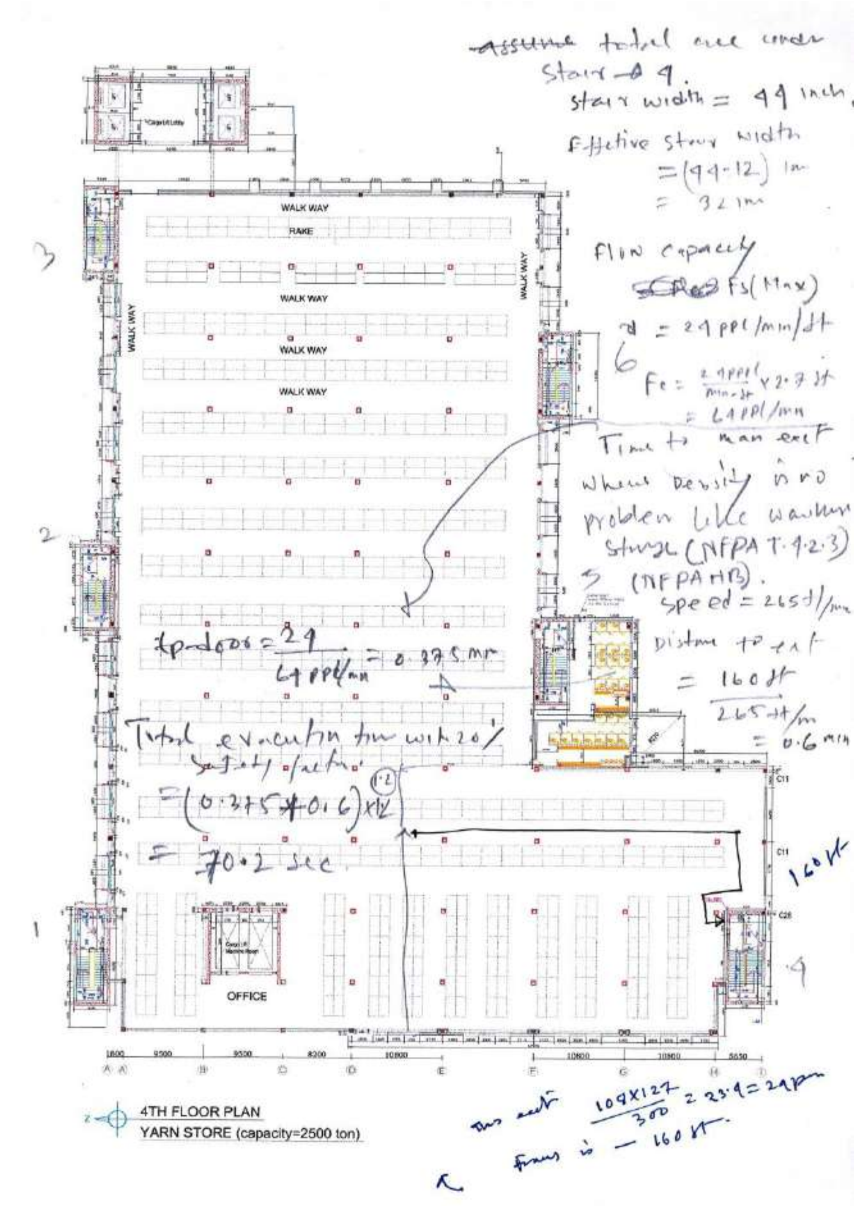
In occupancies other than storage occupancies, the fire is expected to be relatively small, while the occupants are escaping; therefore, an HRRPUA <=1000 kW/m^2 was chosen. For storage facilities a larger value was selected to prevent the footprint of the fire becoming impractical once the fire becomes large; thus, the HRRPUA <=2500 kW/m^2 was chosen at the upper limit.

Performance Test Scenario #1

Performance Test Scenario #1 evaluates the ability to evacuate the fifth floor based on the largest travel distance which is near the rear side of the front elevator. The travel distance is 160 ft., area is approximately 108X127 square feet, and total occupant load is 24 persons. The occupants are occupying the space randomly. The fire's smoke plume will travel up through the open roof. In this scenario, all the occupants do not have a direct view of the fire due to rack storage. However, they would have a clear view of the smoke plume as it rises and occupies the roof area of 108X127 sft. As a result, occupants are expected to detect and notify each other of the fire immediately (within 40 seconds). Pre- evacuation is assumed to take only 30 seconds. Occupants are expect to gather their things and begin to evacuate promptly if they can visually validate an imminent danger. Using the methods and assumptions presented in above, a movement time of 22.5 seconds was calculated for 24 occupants to pass through a 44-inch exit door, traveling maximum 160 feet distance within 35 seconds.

Total = (22.5 sec+35 seconds) X1.2 = 70.2 seconds with 20% safety margin. (See Fig#34

& Table# 42).



Fig#34: Performance Test Scenario #1

Table #42. RSET for Performance Test Scenario #1

RSET=	Detection Phase (Δtd) +	Notification Phase(Δta)+	Pre-Evacuation Phase(Δtpre) +	Evacuation Phase(Δtesc)
RSET	40 seconds	10 seconds	30 seconds	70.2 seconds
RSET= 150 seconds.				

7.13 Performance Test Scenario #2

Performance Test Scenario #2 evaluates the ability to evacuate the entire building. For this scenario, the building has six exits stair in each floor and exit stairs are 2-hour fire rated with 1.5 hour fire rated doors with standard locking system according to NFPA 101. The Fire occurs on the 5th floor and all occupants are required to evacuate from the building. Occupants in this scenario will not have a direct view of the fire and therefore it is assumed that notification will not occur until the fire alarm is activated. Fire alarm activation initiated by water discharging from a fire sprinkler head has been determined to occur approximately 43.2 seconds (1st sprinkler activation time in FDS, ECOTEX1) after the fire starts. The pre-evacuation time for this scenario has been increased to 60 seconds. Occupants are expected to take longer to begin evacuating since they cannot visually validate an imminent danger. Table 43 & 43A summarizes the values used to calculate the total movement time associated with evacuation of the entire building. The total effective widths represent the sum of all six doors/ stairwells on each floor.

As stated above in Section 4.1, this analysis assumes occupants on the lower floors will not evacuate until after occupants on the upper levels have cleared the stairwells. This represents a worst-case scenario. The total movement time, including a 10% safety margin, was calculated to be 1075 seconds (see Figure 51).

Table 43: Total Evacuation Time.

Level	Occupant(ppl)	Total effective stair Width (ft.)	Total effective Door Width (ft.)	Calculated Flow (ppl/min)	Travel Distance (ft.)	Speed of Movement (ft./min)	Total Movement time(min)
0	713	26.16	20	480	170	105	3.10
1	712	26.16	20	480	180	105	3.19
2	712	26.16	20	480	175	105	3.15
3	242	26.16	20	480	160	105	2.02
4	242	26.16	20	480	160	105	2.02
5	242	26.16	20	480	160	105	2.02
Total Movement Time							15.5

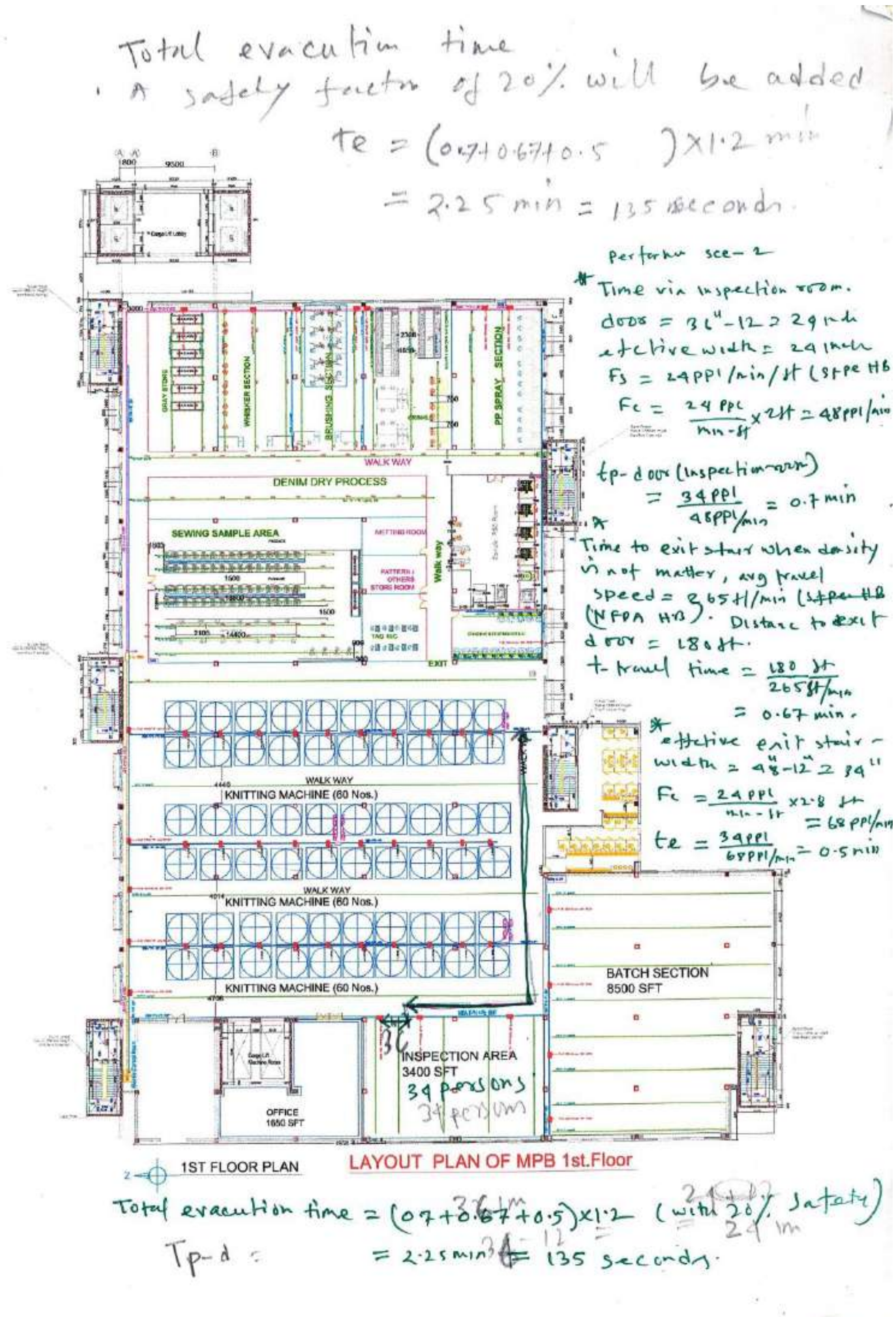
Table 43A: RSET for Performance Test Scenario #2.

RSET =	Detection Phase(Δtd)	Notification Phase (Δta)	Pre-Evacuation Phase (Δtpre)	Evacuation Phase(Δtesc)
RSET	43	5	60	950
RSET=1058 seconds				

Performance Test Scenario #3

Performance Test Scenario #3 evaluates the ability to evacuate the 1st floor based on largest travel distance from the inspection room to stair number-3. The travel distance is 180 ft., area of inspection room is approximately 3400 sft, and total occupant load is 34 people. The occupants are occupying the inspection room and as a result, occupants are expected to detect and notify each other of the fire immediately (within 10 seconds). Pre- evacuation is assumed to take only 30 seconds. Occupants are expect to gather their things and begin to evacuate promptly if they can visually validate an imminent danger. Using the methods and assumptions presented in above, a movement time of seconds was calculated for 34 occupants to pass through a 36-inch inspection room door is 42 seconds, traveling maximum 180 feet distance within 40.2 seconds and time to pass 48 inch exit door is 30 seconds. This analysis is made when active and a passive fire protection has failed as per LSC DF 8.

Total = (42 sec+ 40.2 seconds + 30)X1.2 = 135 seconds with 20% safety margin. (See Fig#35)

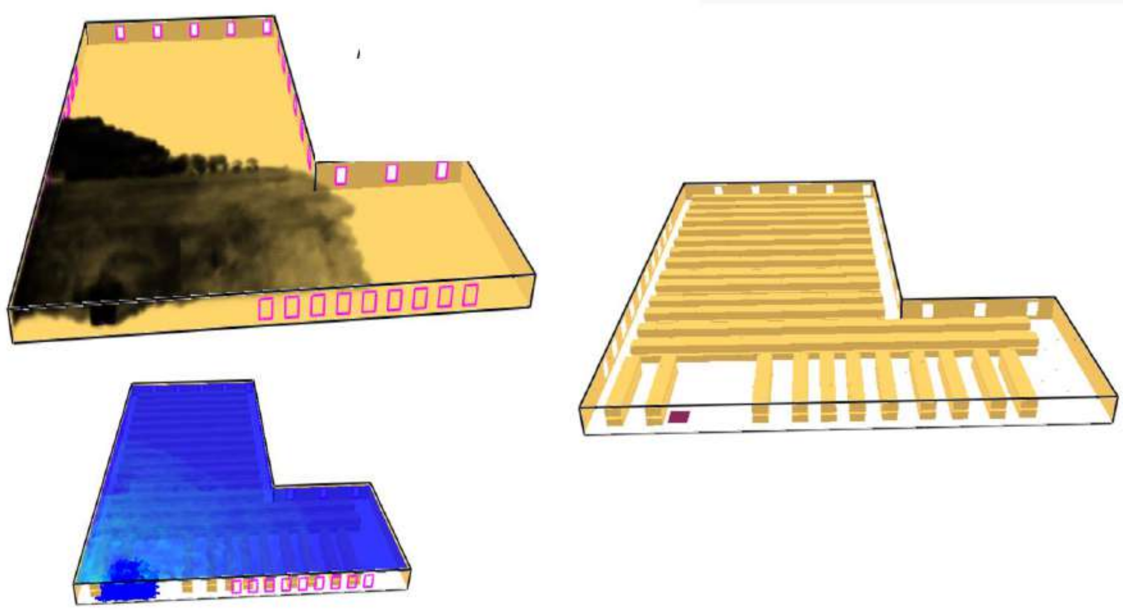


Fig#35: Performance Test Scenario # 3

7.14 Performance Test Results

The FDS (Fire Dynamics Simulator) is one kind of fire simulation software developed by America's national bureau of building Fire research lab record, FDS is a extensively applied in the field of fire safety engineering for performance-based evaluation utilized computational fluid dynamics (CFD) modeling software, used to demonstrate the tenability of the environment for which occupants would be required to evacuate. FDS solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally driven flow with an emphasis on smoke and heat transport from fires. A separate visualization program, Smokeview was utilized to display the results of the FDS simulation. Fig#36 below illustrates how the MPB racks storage was recreated within the FDS software.

The source code for this model is provided in Appendix 7.



Fig#36: MPB Building (Warehouse) in FDS Modeling.

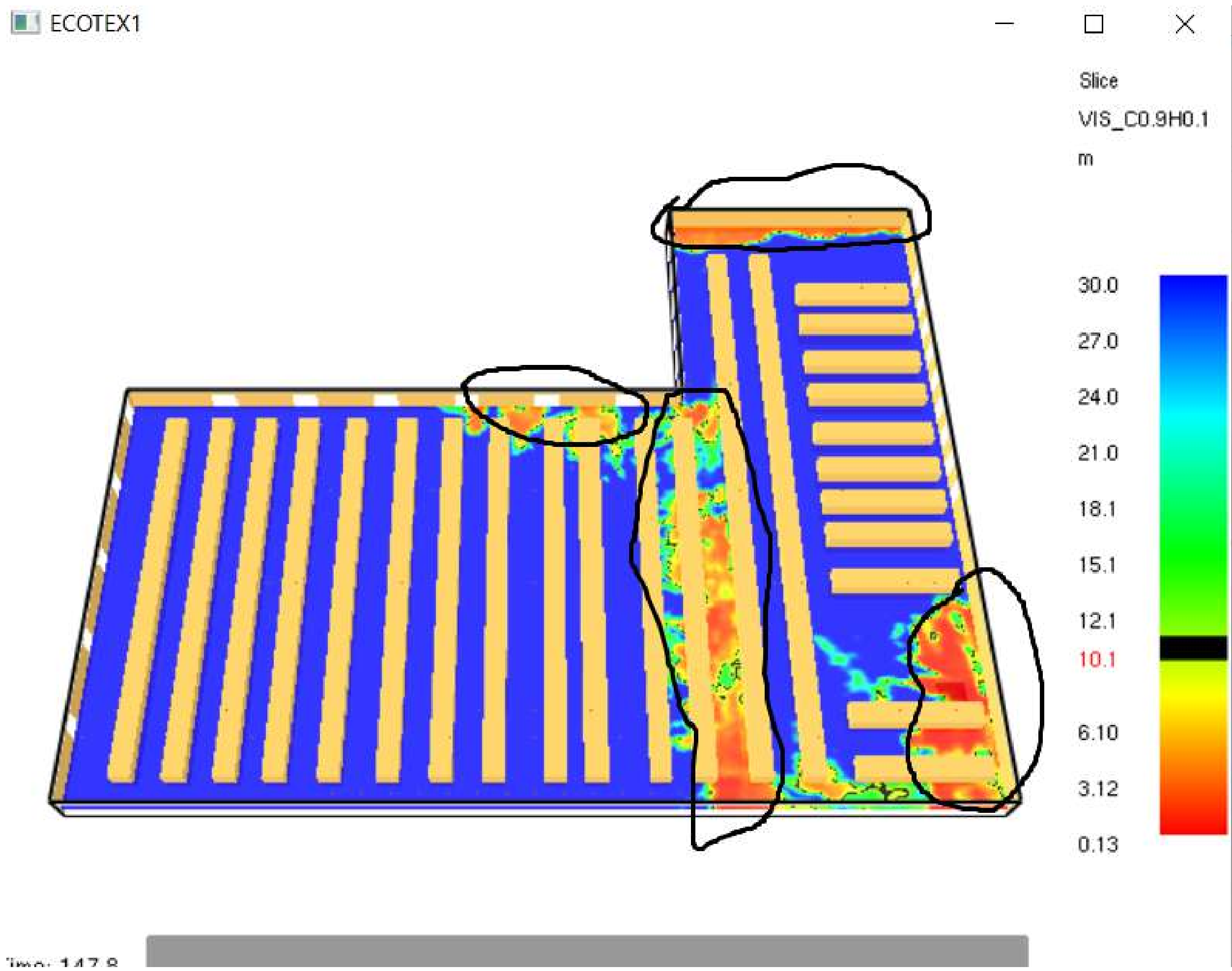
For Performance Test Scenario #1-Results

Visibility, temperature and carbon monoxide levels were all evaluated at six feet above the grade on 5th floor. Visibility is expected to drop below 10 meters in 147 seconds (see Fig#37).The temperature performance criteria of 60°C was never exceeded at 6 ft. (Fig#38.). Carbon monoxide levels reached a maximum concentration of only 730ppm (Fig#38A).

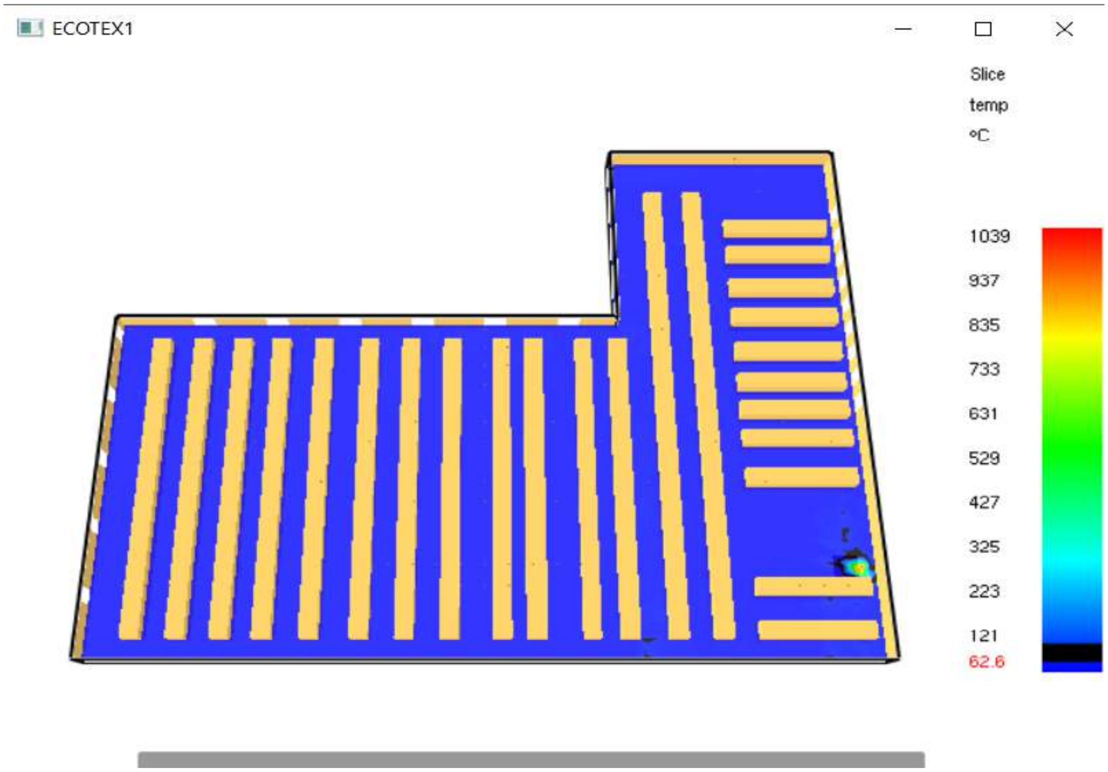
Table 44. Results of Test Scenario #1

Performance criteria			
	Visibility	Temperature	CO
ASET	147 seconds	NA	NA
RSET	150 seconds	150 seconds	150 seconds
Conclusion	Fail	Pass	Pass

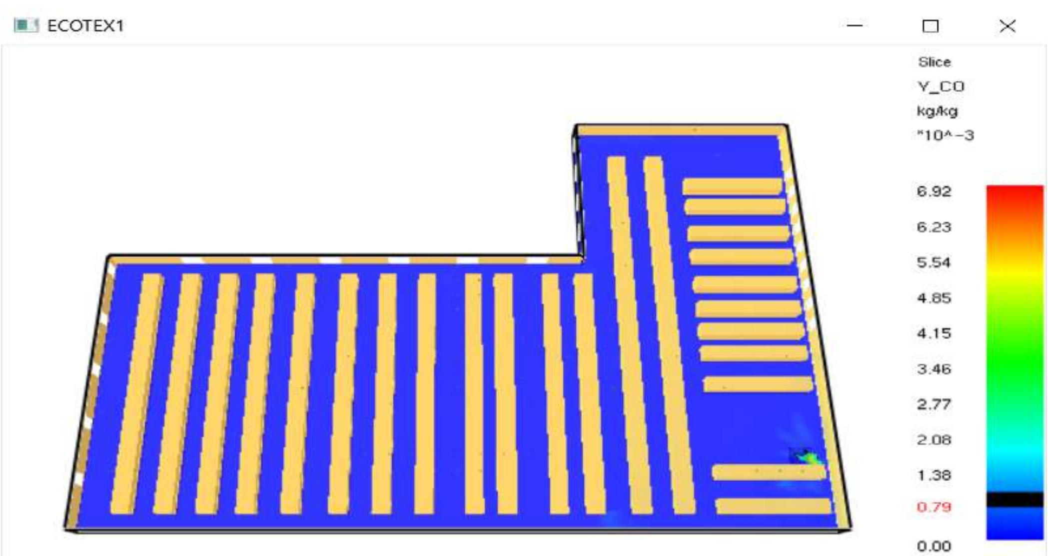
A maximum heat flux of 2kW/m^2 was predicted and Heat flux exposures below 2.5kW/m^2 can be tolerated for several minutes (Fig#38B). As a result, radiant heat flux not anticipated to adversely affect egress. In conclusion, this scenario passes all performance criteria tests except visibility. Table 44 provides a summary of how these results compare to the scenario's RSET.



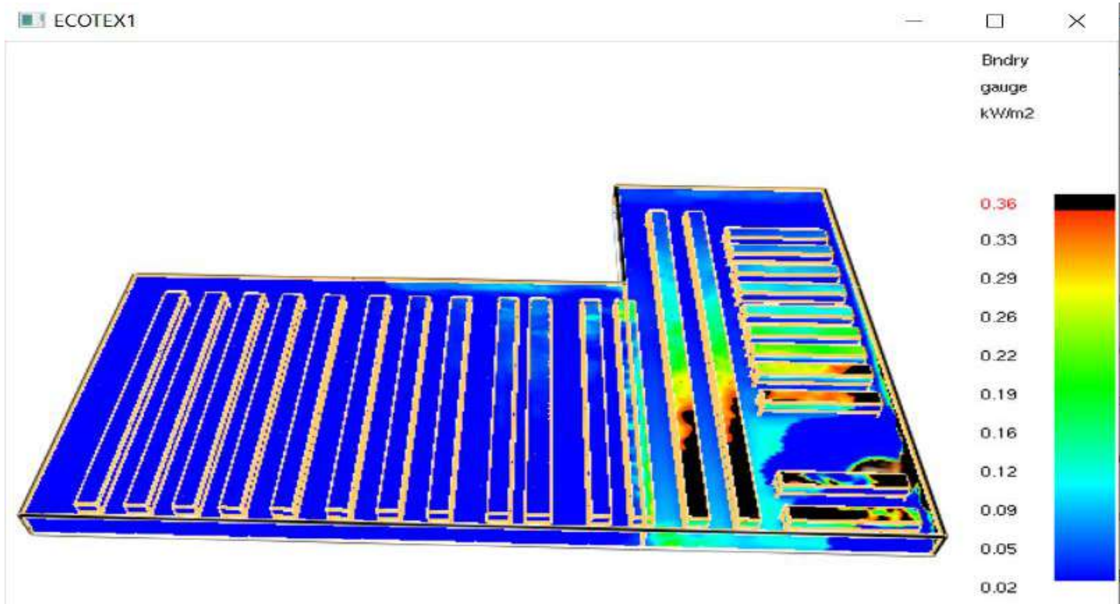
Fig#37: Visibility for Test Scenario #1 at 147 seconds.



Fig#38: Temperature for Test Scenario #1 at 150 seconds



Fig#38A: Carbon monoxide for Test Scenario #1



Fig#38B: Heat Flux (KW/m^2) of MPB building Warehouse at 150 seconds.

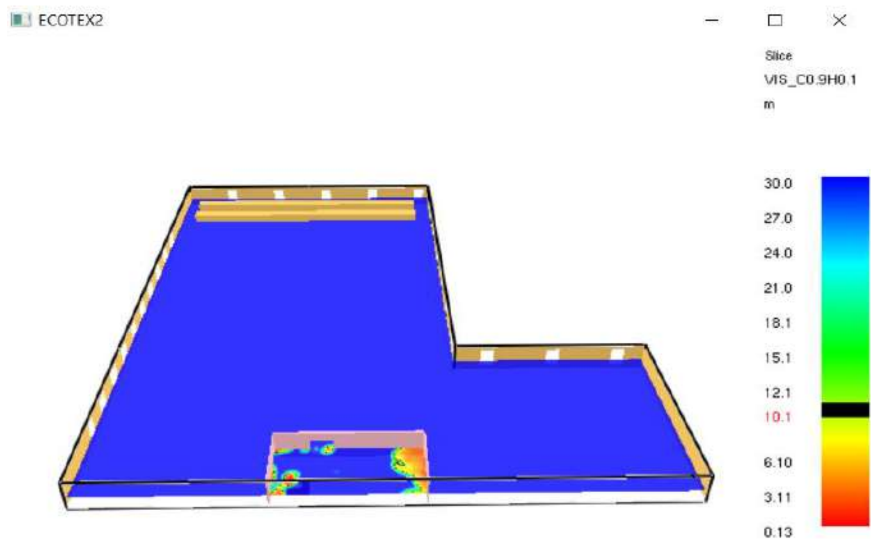
7.15 Performance Test Scenario #3 – Results

Visibility, temperature and carbon monoxide levels were all evaluated at six feet above the 1st floor in Performance Test Scenario #3. Visibility is expected to drop below 10 meters in small area in 42 seconds (see Fig#39) and whole inspection room in 1st floor after 135 seconds (see Fig#39A). The temperature performance criterion of 60°C is less than in 135 seconds (see Fig#39C). Carbon monoxide levels reached a maximum concentration of only 170 ppm (see Fig#39D). Heat flux exposures below 2.5kW/m^2 are shown (See Fig#39E).

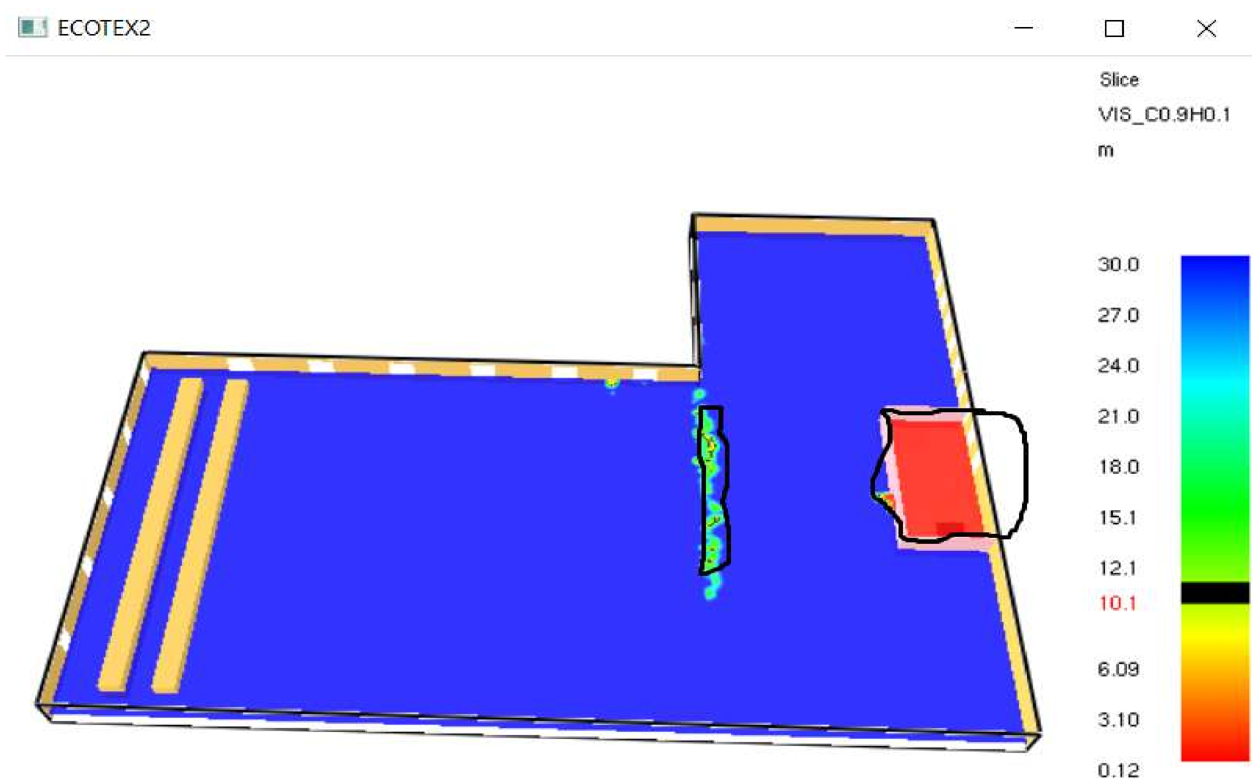
Table 45. Results of Test Scenario #3.

Performance criteria			
	Visibility	Temperature	CO
ASET	144 seconds	NA	NA
RSET	135 seconds	135 seconds	135 seconds
Conclusion	Pass	Pass	Pass

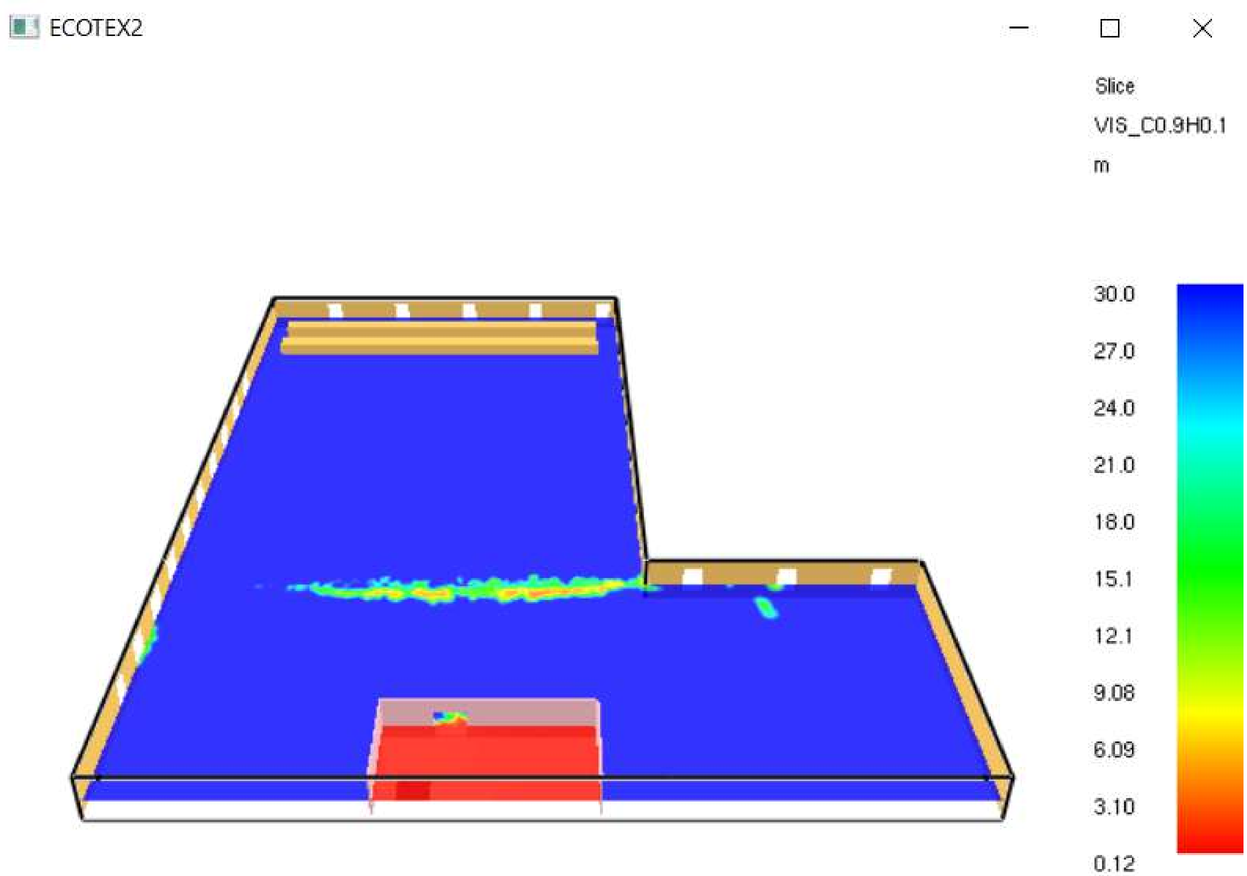
In conclusion, these scenarios pass the performance criteria tests for visibility and temperature. Table 45 provides a summary of how these results compare to the scenario's RSET.



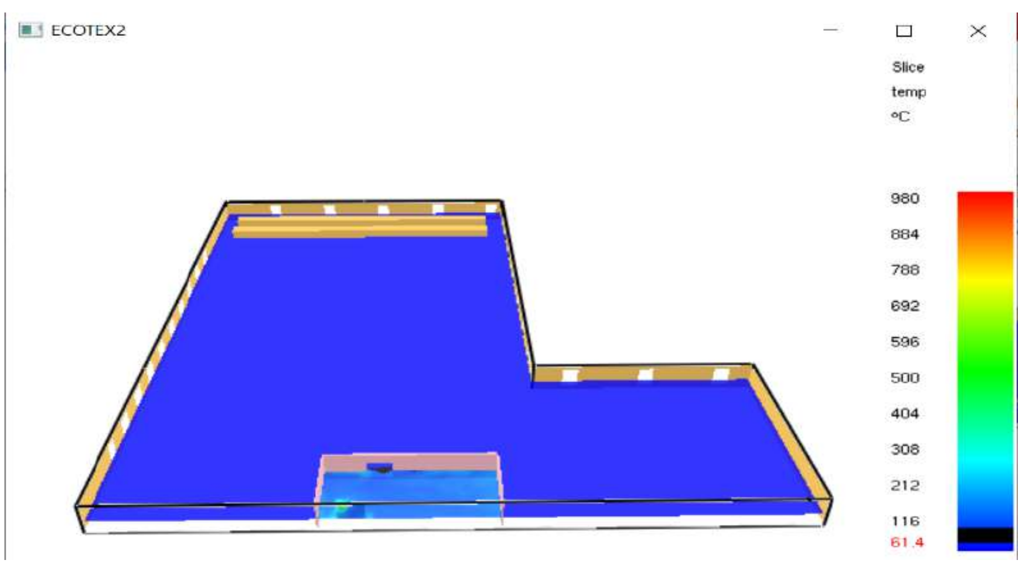
Fig#39: Visibility at 42 seconds for Test Scenario #3



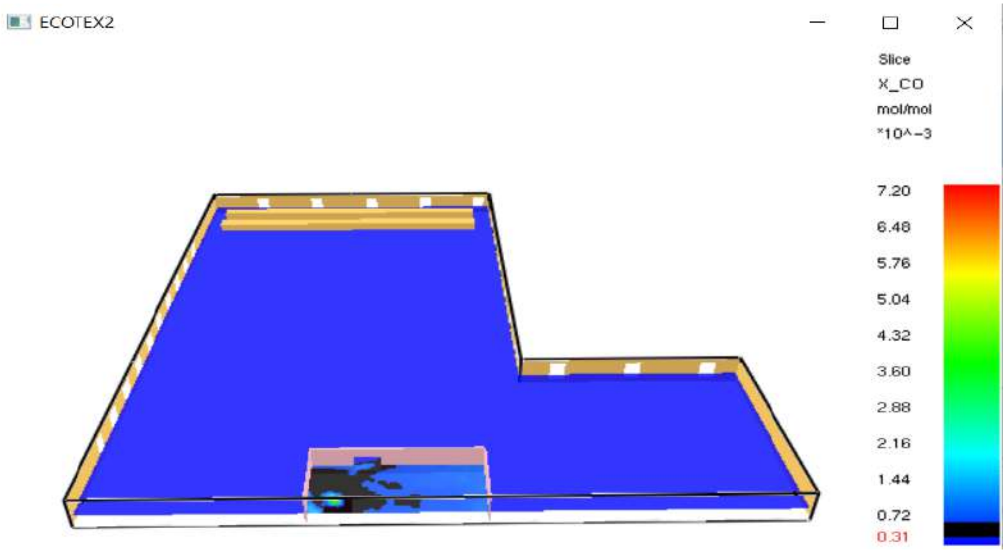
Fig#39A: Visibility at 135 seconds for Test Scenario #3



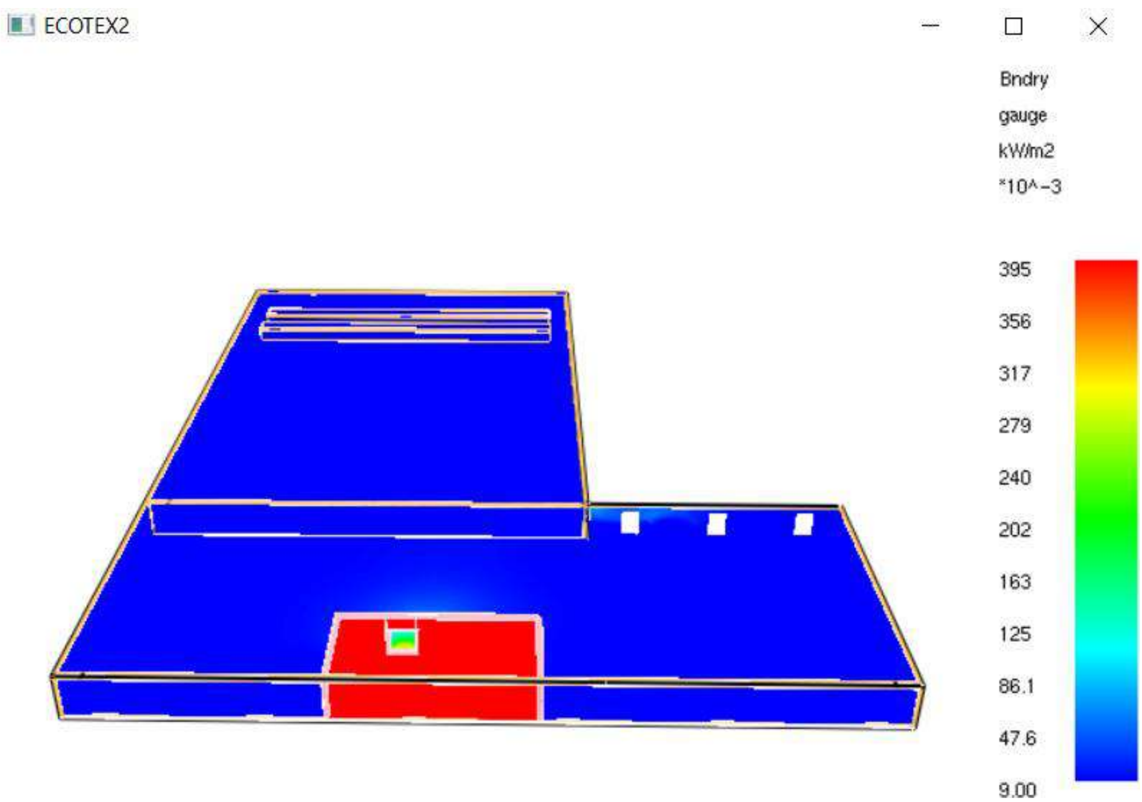
Fig#39B: Visibility at 144 seconds for Test Scenario #3.



Fig#39C: Temperature for Test Scenario #3.



Fig#39D: Carbon Monoxide for Test Scenario #3.



Fig#39E: HEAT FLUX for Test Scenario #3

7.16 Performance Based Structural Fire protections:

Typically, the performance requirements related to fire safety contained in performance-based standards are:

1. To ensure that a fire once started will not spread beyond the room of origin
2. To ensure that occupants will be given early warning of a fire occurrence to enable rapid evacuation from the building.
3. To ensure that the structure will remain standing long enough to allow occupants to escape;
4. To ensure that the structure will remain standing long enough for emergency personnel to perform their duties; and
5. To ensure the burning building will not fall down upon, or ignite the neighboring properties. Similarly, for structural safety, the requirement is to reduce the probability of structural failure, and design the structure in a way that will ensure that the entire structural system will remain stable when a localized collapse occurs. The current prescriptive building codes specify the required FRR for floor and wall assemblies, and structural members based on occupancy, building height, and building construction. Typically these start at a minimum 45 min FRR, followed by 1 hr, 1-1/2 hr, 2 hr and 4 hr ratings, and are applied throughout the building regardless of whether or not the rating is adequate based on actual fire load, risk etc..

To offer a justifiable alternative to this approach that will satisfy the objectives stated above, a performance based design should be based on the following:

1. A fire scenario must be characterized by predicting fire load, fire size, fire severity and fire duration, and a time-temperature relationship for the fire scenario must be calculated;
2. The fire must be modeled in a location that represents a worst-case design for the building. That is, consideration must be given to both structural and fuel load to ensure the modeled compartment is representative of the building. To do this, multiple compartments should be assessed since the worst case fire location is not necessarily a structurally critical region in the building;

3. The time-temperature relationship of the fire exposed steel must be calculated and the thermal response determined relative to the known failure criteria of the member under consideration. Failure times must be based on a clearly defined “pass/fail criteria”; and

3. Use of the “inherent” or implied safety of the prescriptive code as the minimum level of safety to achieve. This can be done by utilizing the fire resistant ratings defined by the prescriptive code as a benchmark for the performance-based code.

7.17 Critical Temperature of Fire-exposed Structural Steel:

During a fire, steel, whether in the form of a column, beam, or truss, will be exposed to hot gases from the fire. Given the high thermal conductivity of steel it is usually assumed that steel will be heated uniformly (Lie, 1992) resulting in a uniform temperature increase throughout the steel member. As a fire within a compartment intensifies, the mechanical properties, such as tensile and yield strength, and modulus of elasticity will decrease. If the yield stress decreases to the working stress (about 50% of initial strength), the element will fail. The steel temperature at this moment is usually taken as the critical temperature. The critical temperature of steel is often taken as 540^0 C (see Table 46), but varies depending upon the type and size of the steel member.

Table 46. Critical temperatures for various types of steel

Steel	Standard/Reference	Temperature
Structural Steel	ASTM	538^0 C
Reinforcing steel	ASTM	593^0 C
Reinforcing steel	ASTM	426^0 C
Reinforcing steel	Euro code 3	350^0 C

By maintaining the steel temperature below the critical temperature it is possible to ensure that the yield strength is not reduced to below 50% of the ambient value (Kodur, 2001). From a design perspective the critical temperature of steel varies depending upon the various types of steel as follow (Pattersson et al., 1976);

Time –Temperature Curve :

Current building code requirements for determining the fire resistance of structural systems are based on the reaction of specimens to a standard fire exposure such as defined by test standards ASTM E119, ISO 834, and NFPA 251.

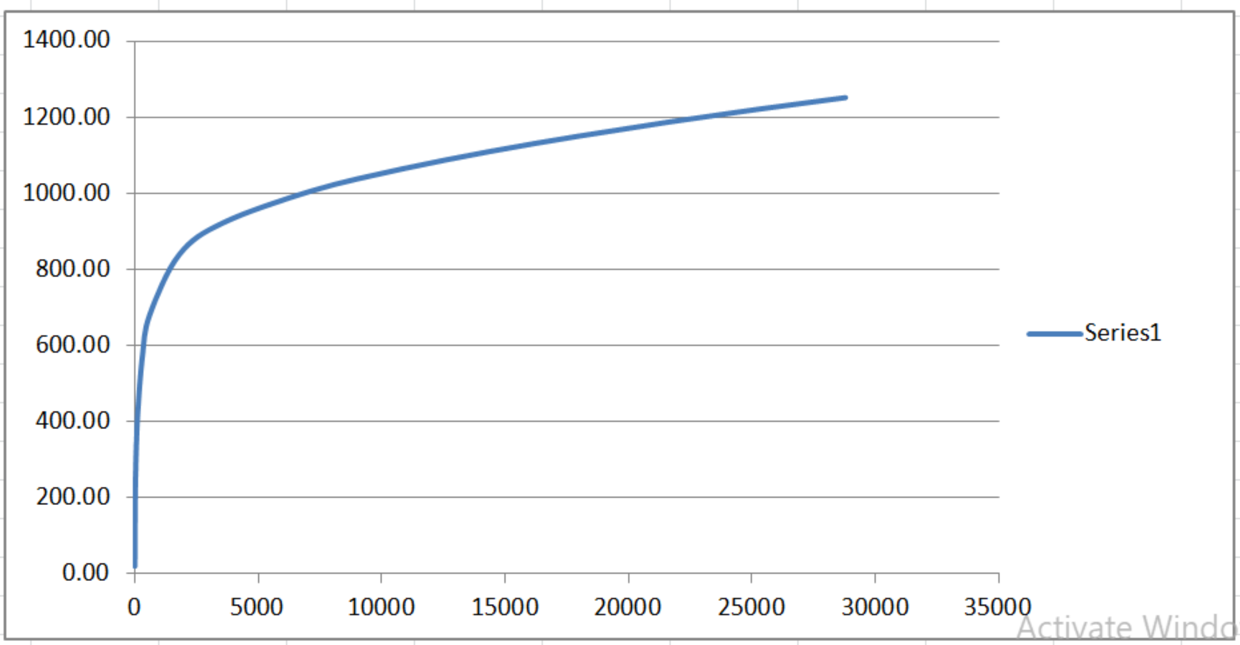
They are based on a specified time-temperature exposure that is not consistent with the characteristics of a real fire.

It is also worth noting that ASTM E-119 states the following:

This standard should be used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions and should not be used to describe or appraise the fire-hazard or fire-risk of materials, products, or assemblies under actual fire conditions. However, results of the test may be used as elements of a fire-hazard assessment or a fire-risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard or fire risk of a particular end use (Fig#40)

I will analyze this fire based on standard time temperature curve which is shows below. Where T = Temperature (^{0}C), t_h = Time (hours), T_o = Initial /ambient temperature.

$T=750[1-e^{-3.79553\sqrt{th}}]+170.41\sqrt{t_h}+T_o$.



Fig#40: Time (X-Axis in Seconds) –Temperature (Y-Axis, in ^{0}C) Curve of ASTM E119.

Based on above curve, a fire we will be analyzed. The typical column strength in unprotected (not insulated) stage and insulated stage if the steel temperature is less than 538^0C.

Unprotected steel member:

There are methods available to account for the potential storage of heat in insulating materials with higher heat capacity. However, it is more conservative to assume that all heat energy is transferred to the steel by ignoring this possibility. The thermal conductivity of materials (ki) typically used for the protection of structural steel. An incremental method will have to be used to solve these equations (See Table#47, CALPOLY FPE S524 course sheet). The accuracy of the resulting answer will increase with smaller values for the time interval. Use of a spreadsheet will permit use of small time steps, typically 1/10th of the total fire duration and will yield acceptable results (Pattersson, 1978).

Table#47: LHCA Calculation Framework.

t (s)	T_s (°C)	T_f (°C)	T_f-T_s (°C)	h_t (W/m^2-°C)	ΔT_s (°C)
10 s (Δt=10 s)	**Initial steel temp., T_{so}**	**T_f @t for this time step**	**Subtract T_s from T_f**	**Evaluate for T_f and T_s in this time step**	**Determine using eqn**
20 s (10+Δt)	**T_s + ΔT_s from previous time step**	**T_f @t for this time step**	**Subtract T_s from T_f**	**Evaluate for T_f and T_s in this time step**	**Determine using eqn**
Etc.					

Input Data:

Emissivity, ε= 0.7 . (See Table #48, Reference SFPE Handbook Table 53.7)

Specific heat of steel, C_s= 600 J/kg-K.

Density of steel, ρ= 7850 kg/m3

ΔT_s= steel temp. Change during time step, Δt (°C).

T_f =temperature of heated environment (°C or K).

Δt =time step, (s)= 10.00 seconds.

h_t =total heat transfer coefficient (radiation and convection) (W/m²-K).

V =volume of steel (m3).

A= exposed steel surface area to heated environment (m²).

W= weight per unit length (kg/m).

D= heated perimeter (m).

Stefan's constant, $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}.

Table#48: Effective emissivity.

Table 53.7 Effective emissivity [40]

Type of construction	Effective Emissivity	
1.	Column exposed to fire on all sides	0.7
2.	Column outside facade	0.3
3.	Floor girder with floor slab of concrete, only the underside of the bottom flange being directly exposed to fire	0.5
4.	Floor girder with floor slab on the top flange	
	Girder of I section for which the width-depth ratio is not less than 0.5	0.5
	Girder of I section for which the width-depth ratio is less than 0.5	0.7
	Box girder and lattice girder	0.7

Analyzing unprotected steel column of W10X49 by following equation.

$$h_t = \frac{\varepsilon\sigma}{T_f - T_s}\left(T_f^4 - T_s^4\right) + 25$$

Seconds	Time	T_s (°C)	T_f (°C)	T_f-T_s (°C)	h_t	ΔT_s (°C)
↘	0	20	20.00	0.00	25	0
	10	20.00	164.96	144.96	33.0703	0.598109
	20	20.60	217.51	196.91	35.1882	0.864486
	30	21.46	255.18	233.72	36.96	1.077744
	40	22.54	285.26	262.72	38.5436	1.263426
1 Min.	50	23.80	310.57	286.77	40.0021	1.431238
	60	25.24	332.53	307.30	41.3689	1.586086

70	26.82	351.98	325.16	42.6643	1.730857		
80	28.55	369.48	340.92	43.9022	1.867415		
90	30.42	385.39	354.97	45.0924	1.997052		
100	32.42	399.99	367.57	46.2423	2.120706		
110	34.54	413.49	378.95	47.3576	2.239089		
120	36.78	426.04	389.27	48.4429	2.352751		
130	39.13	437.78	398.65	49.5021	2.462138		
140	41.59	448.79	407.20	50.5383	2.567608		
150	44.16	459.17	415.02	51.5541	2.669464		
160	46.83	468.99	422.16	52.5519	2.767958		
170	49.60	478.29	428.69	53.5336	2.863307		
180	52.46	487.13	434.67	54.501	2.955698		
190	55.42	495.55	440.14	55.4556	3.045296		
200	58.46	503.59	445.13	56.3988	3.132244		
1150	522.32	778.53	256.21	152.562	4.87688		
1160	527.20	779.76	252.57	153.747	4.844835		
1170	532.04	780.98	248.94	154.933	4.812079		
1180	536.85	782.19	245.33	156.117	4.778632		
1190	541.63	783.38	241.75	157.301	4.744514	19.83333333	19 min 50 seco
1200	546.38	784.56	238.18	158.485	4.709746		
1210	551.09	785.73	234.64	159.667	4.67435		
1220	555.76	786.89	231.13	160.848	4.638346		
1230	560.40	788.04	227.64	162.027	4.601758		
1240	565.00	789.17	224.17	163.204	4.564607		
1250	569.57	790.29	220.73	164.38	4.526916	20 Minutes 50 Seconds	

Within 19 min 50 seconds, unprotected steel column reached 540 ^{0}C.

Protected Steel Column:

MPB Building owner used MONOKOTE MK-6/HY insulation materials for 4 –hour steel column fire rating. I will analyze 4-hour fire rating with the applied insulation thickness of MK-6/HY(see Table#49) whether it meets or not by following calculation and procedure.

Equation, $$\Delta T_s = \frac{k_i}{h_i}\left[\frac{T_f - T_s}{c_s \frac{W}{D} + \frac{c_i \rho_i h_i}{2}}\right]\Delta t$$

Input Data.

Properties of insulation materials

K=0.116W/m-K.

C=1825 J/kg-K

Density = 240 kg/m^3.

Moisture content =48 kg/m^3.

Convective coefficient (hot) =25 W/m^{2}K.

Convective coefficient (cold) =5 W/m^{2}K.

Emissivity =0.7.

Applied thickness, h_i= 34 mm=1.34 inch=0.034036 meter.

W= weight per unit length (kg/m).

D= heated perimeter (m)

W/D=2.28

Table 49: Detail Specification of MK-6/HY:

Performance Characteristics

Physical Properties	Recommended Specification	Laboratory Tested* Values	Test Method
Dry density, minimum average	15 pcf (240 kg/m³)	15 pcf (240 kg/m³)	ASTM E605
Bond strength	200 psf (9.6 KPa)	352 psf (16.9 KPa)	ASTM E736
Compression, 10% deformation	8.3 psi (51 kPa)	32 psi (220 KPa)	ASTM E761
Air erosion	Max 0.000 g/ft² (0.00 g/m²)	0.000 g/ft² (0.00 g/m²)	ASTM E859
High velocity air erosion	No continued erosion after 4 hours	No continued erosion after 4 hours	ASTM E859
Corrosion	Does not contribute to corrosion	Does not contribute to corrosion	ASTM E937
Bond impact	No cracking, spalling or delamination	No cracking, spalling or delamination	ASTM E760
Deflection	No cracking, spalling or delamination	No cracking, spalling or delamination	ASTM E759
Resistance to mold growth	No growth after 28 days	No growth after 28 days	ASTM G21
Surface burning characteristics	Flame spread = 0 Smoke developed = 0	Flame spread = 0 Smoke developed = 0	ASTM E84
Combustibility	Less than 5 MJ/m² total, 20 kw/m² peak heat release	Less than 5 MJ/m² total, 20 kw/m² peak heat release	ASTM E1354
Impact penetration	Max 6 cm³ abraded	3.9 cm³	City of San Francisco
Abrasion resistance	Max 15 cm³ abraded	8.3 cm³	City of San Francisco

*Actual laboratory tested values meet or exceed GCP's recommended value. Test reports are available on request from your GCP sales representative.

By applying above equation for protracted steel column:

Seconds	Time	T_s (°C)	T_f (°C)	T_f-T_s (°C)	k/h	ΔT_s (°C)
↘	0	20.00	20.00	0.00	3.41	0.00
	10	20.00	164.96	144.96	3.41	0.06
	20	20.06	217.51	197.45	3.41	0.08
	30	20.13	255.18	235.04	3.41	0.09
	40	20.22	285.26	265.04	3.41	0.10
	50	20.33	310.57	290.24	3.41	0.11
	60	20.44	332.53	312.09	3.41	0.12
	70	20.56	351.98	331.42	3.41	0.13
	80	20.69	369.48	348.78	3.41	0.14
	90	20.83	385.39	364.56	3.41	0.14
	100	20.97	399.99	379.02	3.41	0.15
	110	21.12	413.49	392.37	3.41	0.15
	120	21.27	426.04	404.78	3.41	0.16
	130	21.43	437.78	416.35	3.41	0.16
	140	21.59	448.79	427.21	3.41	0.17
	150	21.75	459.17	437.42	3.41	0.17
	160	21.92	468.99	447.06	3.41	0.17
	170	22.10	478.29	456.19	3.41	0.18
	180	22.28	487.13	464.85	3.41	0.18
	14350	434.27	1109.84	675.58	3.41	0.26
	14360	434.53	1109.96	675.43	3.41	0.26
	14370	434.79	1110.08	675.29	3.41	0.26
	14380	435.06	1110.20	675.15	3.41	0.26
	14390	435.32	1110.32	675.00	3.41	0.26
4 Hour	14400	435.58	1110.44	674.86	3.41	0.26

After 4 hour, temperature of steel column is 436 ^{0}C which is less than the 540 ^{0}C.

Appendix-12: Structural Fire Protection Assessment. Appendix-11: Structural Fire Protection Catalog. Appendix-9: Fire Alarm catalog. Appendix-10: Sprinkler Catalog.

7.18 Conclusion/ Recommendations

The prescriptive based analysis revealed that the MPB's structural design, fire alarm and fire suppression systems meet respective codes requirements. The construction type, number of stories, floor area and fire resistance all comply with International Building Code requirements. Fire initiating devices are correctly spaced throughout the building and initiate prudent corrective actions. Emergency communication is available and messages distributed throughout the building are intelligible. Fire sprinklers and hose connections are adequately provided. An assessment of the water demand demonstrated that the water supply is sufficient for the most remote locations of the building.

The majority of the building's egress system was found to be in compliance. A sufficient number of exits are provided. These exits are appropriately separated to reduce the probability of a single event rendering multiple exits unusable. No issues related to common path of travel or dead end distances were identified.

A performance-based analysis was also conducted to evaluate the effectiveness of these fire, life safety systems and structural fire protection. The Available Safe Egress Time (ASET) and Required Safe Egress Time (RSET) were different for each test as they were based on parameters unique to each scenario. The RSET (visibility) exceeded slightly the ASET in Performance Test Scenario #1 because of assuming worst case HRRPUA (2500 kW/m^2) in the fire model (ECOTEX1) which may be less in actual fire in rack storage on 5th floor. Furthermore, steel column fire protection was analyzed using MONOKOTE MK-6/HY insulation materials to check the steel column maximum temperature of 4360C after 4 –hour which is less than 540^0C and which meet the building code and standard.

One recommendation made is to reduce 2nd floor existing occupant load to 712 persons as present occupant found 1000 persons at actual and maximum 2nd floor capacity is 712 persons due to occupancy classifications.

Fire Safety Management Plan

MPB Building

8.1 Introduction

A Fire Safety Management Plan has been developed to inform occupants of their roles and actions to take in the event of a fire to ensure the safety of building occupants. The primary objective of this plan is to prevent injuries to its employees, contractors and visitors. It is the duty of all employees, contractors and occupants to review this plan and understand their roles and actions to take during an emergency.

8.2 Building Information

The BPB is a six story building located in Chandra, Gazipur , Bangladesh. This facility was designed to provide over 210000 square feet of factory space to approximately 2127 employees capacity in 1st three floor where actual capacity of 1000 occupants shall be cut down to 712and other three floors have 726 storage occupants . Additional building details are provided below:

- Address = EchoTex Ltd.
  Polli Biddut, Chandura,
  Kaliakoir,Gazipur,
  Banglaesh
- Building Height = 111'-5"
- Number of Stories = 6

8.3 Occupancy Classification

In accordance with the *International Building Code (IBC*), the intended use of each portion of the building was individually assessed and assigned an occupancy classification. The majority of the building is used for factory and storage occupancy and considered a mix Group Occupancy.

In addition to factory and stoarge space, the MBP building also has several others occupancy like business, utility.

Figure 1 provides an illustration of how different spaces on the 1st floor of the BPB building are used/ classified. Illustrations for the remaining floors can be found in Appendix 1.

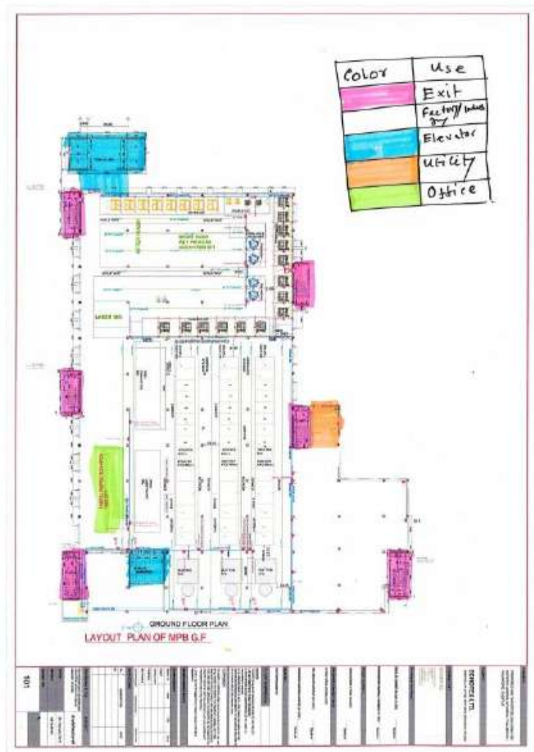


Figure 1. MBP Area Uses (Ground floor).

8.4 Construction Type

The BPB was constructed of protected non-combustible materials in accordance with Type IA-B building specifications.

8.5 Occupant Load

A building's occupant load is determined by dividing a space's area by an occupant load factor specified for that space. Since spaces used for different purposes will have different occupant densities, the occupant load factor is based on the actual use of a space and not the occupancy classification of the building or space.

Table 1 shows the different uses/ space functions found on each level as well as their combined areas. These areas were divided by the occupant load factors prescribed by the *Life Safety Code* to determine each space's occupant load. Ground has the highest total occupant load due to the densely populated factory areas located on this level.

Table 1: BPB Occupant Loads

Level	**Function of Space**	**Area (sf)**	**Occupant Load Factor (sq. ft./occupant)**	**Calculated Occupant Load**	**Total Occupant Load**
Gr. floor	Business	1850	100 gross	19	713
	Factory	68750	100 gross	688	
	Utility	1700	300 gross	6	
1	Business	3400	100 gross	34	712
	Factory	64900	100 gross	672	
	Utility	1700	300 gross	6	
2	Business	3400	100 gross	34	712
	Factory	64900	100 gross	672	
	Utility	1700	300 gross	6	
3	Storage	70600	300 gross	236	242
	Utility	1700	300 gross	6	
4	storage	70600	300 gross	236	242
	Utility	1700	300 gross	6	
5	Storage	70600	300 gross	236	242
	Utility	1700	300 gross	6	
Total					**2863**

8.6 Fire Resistance

Due to MPB Building's Type I-A/1-B construction and separation distance, the building's structural elements were required to meet a minimum 3/2-hour fire resistance rating. Furthermore, specific portions of the building were required to be separated from adjacent areas by fire resistive materials. These areas include the following:

- Stairwells (2-hour fire-resistance rating);
- Elevator Shafts (2-hour fire-resistance rating);
- Exit Passageways (2-hour fire-resistance rating); and,
- Business occupancy to storage occupancy (1-hour fire-resistance rating).

CODE COMPLIANCE ANALYSIS OF STRUCTURAL FIRE PROTECTION :

All of the MPB building elements studied, both structural and non-structural, appears to comply with the IBC requirements for Type I-B construction, suitable for Group F-2 occupancy. The SFRM-protected steel columns fall under CEN. (European Committee of standardization). All the different type of fire protection is provided as per CEN.

Systems of Fire Protection:

Sprinkler System:

- Designing, installation, inspection and maintenance according to accredited codes and regulation includingNFPA13.
- Required fire pumps shall be installed and maintained according to accredited codes and standards.
- Entire building should be protected by sprinkler system.
- A sprinkler system exists throughout the entire building and with zone control valve are connected with FACP to initiate fire alarm throughout the building

Detection and Alarm System:

- Designing, installation, inspection and maintenance according to accredited codes and regulation including NFPA 72.

- Entire building should be protected by detection and alarm system.

•Smoke detectors are located at elevator lobby, machine room and electrical room separated by 2-hour rating from other occupancy of the building and are connected to a fire alarm control panel located in the ground floor of security room.

Structural Fire Protection:

- Installation, inspection and maintenance to Fire Barriers shall be according to accredited Codes and regulation.

- All penetrations of walls, floors and ceilings to be sealed on both sides with rated fire stopping materials and acoustical sealant in order to maintain the integrity of the wall and avoid transmission of sound.

• Implementation of structural fire protection calculation is followed to SFPE Handbook.

Means of Egress:

- Installation, inspection, maintenance and design for means of egress shall comply with NFPA 101, IBC & BNBC (Bangladesh National building code).

•All stairwells in the building are equipped with emergency lighting.

- **Badge Access** - Stairwell Doors and Lobby Doors unlock automatically when a Fire Alarm is activated. Elevator badge requirements unlock automatically when a Fire Alarm is activated, but should not be used for evacuation unless otherwise notified.
- **Emergency Power -** An emergency generator or battery will supply power to emergency lighting and exit signs to provide adequate lighting for evacuation purposes for prescribed time.
- **Suppression Equipment -** Fire extinguishers are located in recessed boxes on each floor. Fire extinguishers are not to be used by Company employees unless training has been received.

8.7 Fire Procedures

In the event of a fire, all employees, contractors and visitors shall follow the instructions described below.

Instructions for the individual who discovers Fire or Smoke:

- Remove anyone from immediate danger.
- Do not attempt to fight the fire unless you have been trained and have assistance.
- Confine the fire or smoke by closing doors if possible as you evacuate the area.
- Immediately notify individuals near the area of the fire.
- Pull the Fire Alarm located at each stairwell exit.
- If safety is not in jeopardy, call **fire service and police** and provide the following information:

  Building name: MPB Building.

  Building address: EchoTex Ltd. Polli Biddut, Chandura, Kaliakoir,Gazipur,Bangladesh

  Nearest cross street: Dhaka-Chandra high way

  Location (Floor, room, etc.) of fire,

  Your call back number: (**XXX) XXX-XXXX**

  <u>DO NOT HANG UP UNTIL THE OPERATOR DOES SO FIRST</u>

- Evacuate the building using a stairwell located at around the floors of the building to the nearest Mustering Point (see Appendix A for Mustering Points).

Instructions for building occupants in the event of a fire alarm:

- Pay attention to the Floor Warden's instructions.
- Evacuate the building using a stairwell located at the ends of each hall and exit the building to the nearest Mustering Point (see Appendix 2 for Exit Routes & Mustering Points).

8.8 Emergency Evacuation Procedures:

- Pull the nearest pull station
- Determine extent of the fire
- Call the fire department
- Attempt to extinguish the fire
- Ensure evacuation, personnel assembly, fire assembly point
- Account for all personnel on site
- Evacuation plan must be available and posted throughout construction site at all time.

- Remain calm
- Be quiet during drills and evacuations so that emergency instructions can be heard and clearly understood.
- Only take your essential personal possessions, wallet, purse and/or keys. Do not take your laptop or other work related material as this could compromise your safety during an evacuation. There will be no re-entry into the building during an emergency.
- Give priority to the movement of nervous or emotional individuals.
- When using the stairwells, high-heeled shoes should be removed in order to reduce risk of injury to yourself or others.
- Always go down the inside of the stairwell, as there is a continuous handrail.
- Elevator are not means of escape .

- Once you have exited the building, proceed immediately to your designated muster point. Remain in the designated muster point so you may be accounted for and await further instructions. Primary building entryways and adjacent driveways should be clear for first responders. Review Appendix 2 for Exit Routes & Mustering Points.

8.9 Mobility-Impaired

- Complete Appendix 3 and send to the MPB building Security Manager. All information will be kept confidential and used for evacuation purposes only. The Security Manager will confidentially notify the area Floor Warden.
- During evacuations, the Floor Warden will ensure first responders assist mobility-impaired

individuals.

- If an individual cannot use the stairwells, they must remain on the stairwell landing and the Floor Warden will notify the first responders of the situation.
- If an individual stays behind after the floor has been evacuated, they must move into a stairwell landing and close the door. They must not block the stairs.

8.10 Training

- All building occupants must be provided a copy and trained annually on the building Fire Safety Management Plan. New occupants must receive this information within 14 days of occupying the building.
- Floor Wardens must receive training at least annually. New Floor Wardens must receive training shortly after being appointed.
- Building occupants must attend regularly scheduled meetings/drills to ensure their proficiency during an emergency. This should include training on Floor Warden Procedures to enable them to assist occupants in the event that Floor Wardens are not available during an emergency.

8.11 Building Owner Responsibilities

The building owner is responsible for preparing a Fire Management Plan and ensuring the building complies with the Fire Code (NFPA 1). The following responsibilities are prescribed in NFPA 1 for the owner, operator, or occupant:

- They must notify the AHJ prior to a change of occupancy as specified in 4.5.7 and 10.3.4 of NFPA 1.
- The AHJ is be permitted to require the owner, operator, or occupant to provide tests or test reports, without expense to the AHJ, as proof of compliance with the intent of this *Code*.

The owner, operator, or occupant of a building that is deemed unsafe by the AHJ must abate, through corrective action approved by the AHJ, the condition causing the building to be unsafe either by repair, rehabilitation, demolition, or other corrective action approved by the AHJ.

Any person in control of a building or premises must keep records of all maintenance, inspections, and testing of fire protection systems, fire alarm systems, smoke control systems, emergency evacuation and relocation drills, emergency action plans, emergency power, elevators, and other equipment as required by the AHJ.

All records required to be kept are to be maintained until their useful life has been served, as required by law, or as required by the AHJ.

8.12 Maintenance Plan

In addition to the aforementioned responsibilities, the building owner, operator, or occupant must ensure the building's fire safety equipment is properly maintained. All inspections, tests, and maintenance shall be documented in a written record.

8.13 Portable Fire Extinguishers

Note: Supplementary information for inspection, maintenance and testing of portable fire extinguishers can be found in NFPA 10.

Table 7.3.3.1 Maintenance Involving Internal Examination

Extinguisher Type	Internal Examination Interval (years)
Stored-pressure loaded stream and antifreeze	1
Pump tank water and pump tank, calcium chloride based	1
Dry chemical, cartridge- and cylinder-operated, with mild steel shells	1*
Dry powder, cartridge- and cylinder-operated, with mild steel shells	1*
Wetting agent	1
Stored-pressure water	5
AFFF (aqueous film-forming foam)	3†
FFFP (film-forming fluoroprotein foam)	3†
Stored-pressure dry chemical, with stainless steel shells	5
Carbon dioxide	5
Wet chemical	5
Dry chemical stored-pressure, with mild steel shells, brazed brass shells, and aluminum shells	6
Halogenated agents	6
Dry powder, stored-pressure, with mild steel shells	6

*Dry chemical and dry powder in cartridge- or cylinder-operated extinguishers are examined annually.

†The extinguishing agent in liquid charge-type AFFF and FFFP extinguishers is replaced every 3 years, and an internal examination (teardown) is normally conducted at that time.

Table 8.3.1 Hydrostatic Test Intervals for Extinguishers

Extinguisher Type	Test Interval (years)
Stored-pressure water, water mist, loaded stream, and/or antifreeze	5
Wetting agent	5
AFFF (aqueous film-forming foam)	5
FFFP (film-forming fluoroprotein foam)	5
Dry chemical with stainless steel shells	5
Carbon dioxide	5
Wet chemical	5
Dry chemical, stored-pressure, with mild steel shells, brazed brass shells, or aluminum shells	12
Dry chemical, cartridge- or cylinder-operated, with mild steel shells	12
Halogenated agents	12
Dry powder, stored-pressure, cartridge- or cylinder-operated, with mild steel shells	12

8.14 Fire Sprinkler System

Note: Supplementary information for inspection, maintenance and testing of fire sprinkler systems can be found in NFPA 25.

Table 5.1.1.2 Summary of Sprinkler System Inspection, Testing, and Maintenance

Item	Frequency	Reference
Inspection		
Control valves		Chapter 13
Fire department connections		Chapter 13
Gauges (wet and deluge systems)	Quarterly	Chapter 13
Gauges (dry and preaction systems)	Monthly/quarterly	Chapter 13
Hanger/braces/supports	Annually	5.2.3
Heat tracing	Per manufacturer's requirements	5.2.6
Hydraulic design information sign	Annually	5.2.5
Information signs	Annually	5.2.7, 5.2.8, 5.2.9
Internal piping condition		Chapter 14
Pipe and fittings	Annually	5.2.2
Sprinklers	Annually	5.2.1
Sprinklers (spare)	Annually	5.2.1.4
Supervisory signal devices (except valve supervisory switches)	Quarterly	5.2.4
System valves		Chapter 13
Valve supervisory signal devices	Quarterly	5.2.4
Waterflow alarm devices	Quarterly	5.2.4
Test		
Antifreeze solution	Annually	5.3.3
Control valves		Chapter 13
Gauges	5 years	Chapter 13
Main drain		Chapter 13
Sprinklers	At 50 years and every 10 years thereafter	5.3.1.1.1, 5.3.1.1.1.1, 5.3.1.1.1.2
Sprinklers	At 75 years and every 5 years thereafter	5.3.1.1.1.5
Sprinklers (dry)	10 years and every 10 years thereafter	5.3.1.1.1.6
Sprinklers (extra high or greater temperature solder type)	5 years	5.3.1.1.1.4
Sprinklers (fast-response)	At 20 years and every 10 years thereafter	5.3.1.1.1.3
Sprinklers (harsh environments)	5 years	5.3.1.1.2
Supervisory signal devices (except valve supervisory switches)		Chapter 13
System valves		Chapter 13
Valve supervisory signal devices		Chapter 13
Waterflow alarm devices (Mechanical)	Quarterly	5.3.2.1
Waterflow alarm devices (vane and pressure switch type)	Semiannually	5.3.2.2
Maintenance		
Low-point drains (dry pipe and preaction systems)		Chapter 13
Sprinklers and automatic spray nozzles protecting commercial cooking equipment and ventilation systems	Annually	5.4.1.7
Valves (all types)		Chapter 13
Investigation		
Obstruction		Chapter 14

8.15 Fire Pumps

Note: Supplementary information for inspection, maintenance and testing of fire pumps

Table 5.1.1.2 Summary of Sprinkler System Inspection, Testing, and Maintenance

Item	Frequency	Reference
Inspection		
Control valves		Chapter 13
Fire department connections		Chapter 13
Gauges (wet and deluge systems)	Quarterly	Chapter 13
Gauges (dry and preaction systems)	Monthly/quarterly	Chapter 13
Hanger/braces/supports	Annually	5.2.3
Heat tracing	Per manufacturer's requirements	5.2.6
Hydraulic design information sign	Annually	5.2.5
Information signs	Annually	5.2.7, 5.2.8, 5.2.9
Internal piping condition		Chapter 14
Pipe and fittings	Annually	5.2.2
Sprinklers	Annually	5.2.1
Sprinklers (spare)	Annually	5.2.1.4
Supervisory signal devices (except valve supervisory switches)	Quarterly	5.2.4
System valves		Chapter 13
Valve supervisory signal devices	Quarterly	5.2.4
Waterflow alarm devices	Quarterly	5.2.4
Test		
Antifreeze solution	Annually	5.3.3
Control valves		Chapter 13
Gauges	5 years	Chapter 13
Main drain		Chapter 13
Sprinklers	At 50 years and every 10 years thereafter	5.3.1.1.1, 5.3.1.1.1.1, 5.3.1.1.1.2
Sprinklers	At 75 years and every 5 years thereafter	5.3.1.1.1.5
Sprinklers (dry)	10 years and every 10 years thereafter	5.3.1.1.1.6
Sprinklers (extra high or greater temperature solder type)	5 years	5.3.1.1.1.4
Sprinklers (fast-response)	At 20 years and every 10 years thereafter	5.3.1.1.1.3
Sprinklers (harsh environments)	5 years	5.3.1.1.2
Supervisory signal devices (except valve supervisory switches)		Chapter 13
System valves		Chapter 13
Valve supervisory signal devices		Chapter 13
Waterflow alarm devices (Mechanical)	Quarterly	5.3.2.1
Waterflow alarm devices (vane and pressure switch type)	Semiannually	5.3.2.2
Maintenance		
Low-point drains (dry pipe and preaction systems)		Chapter 13
Sprinklers and automatic spray nozzles protecting commercial cooking equipment and ventilation systems	Annually	5.4.1.7
Valves (all types)		Chapter 13
Investigation		
Obstruction		Chapter 14

can be found in NFPA 72.

Smoke Detectors

Note: See NFPA 72 for information on inspection, maintenance and testing of smoke detectors.

8.16 MPB Area Uses

Fig: 4th floor occupancy area.

Fig: 3rd floor occupancy plan.

Fig: 5th floor occupancy.

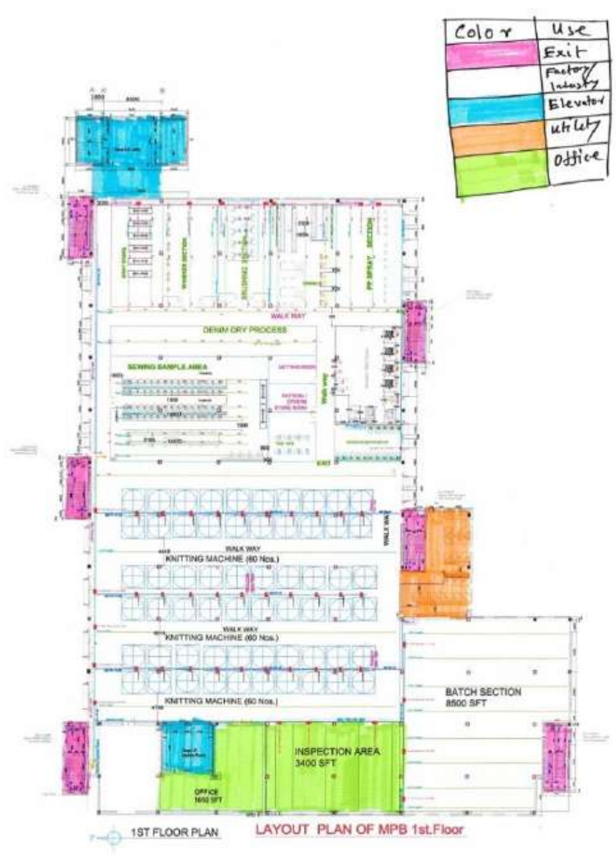


Fig: 1st & 2nd floor occupancy plan.

Fig: Ground floor occupancy plan.

8.17 Exits & Muster Points.

•

Fig : 4th floor exit plan

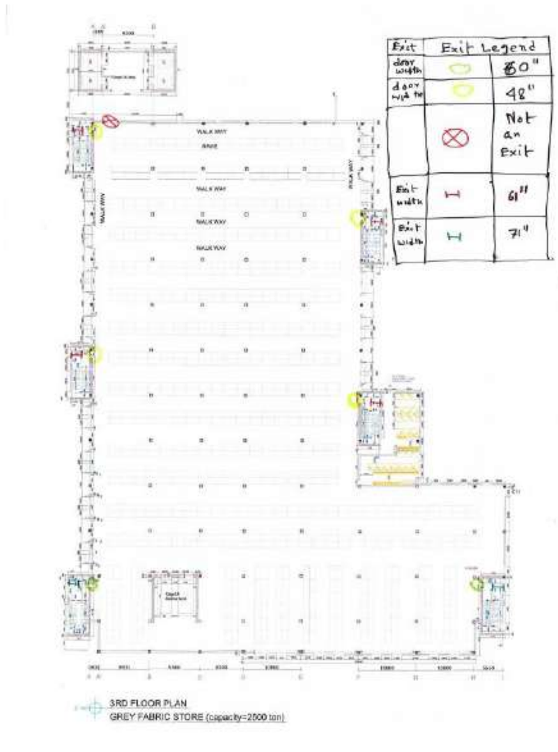


Fig: 3rd floor exits plan.

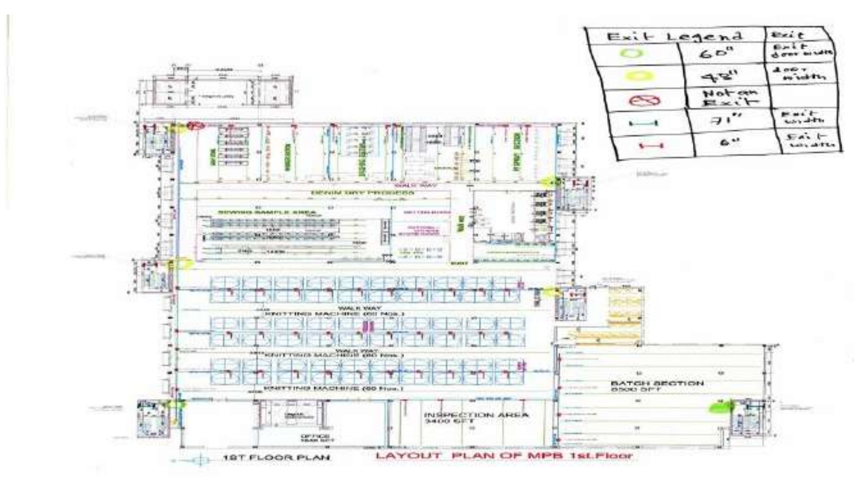


Fig: 1st & 2nd floor exits plan.

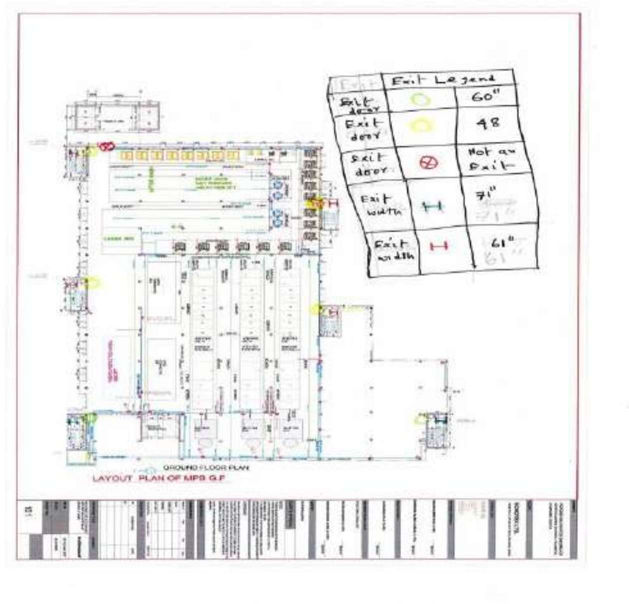


Fig: Ground floor exits plan.

8.18 Exits signs.

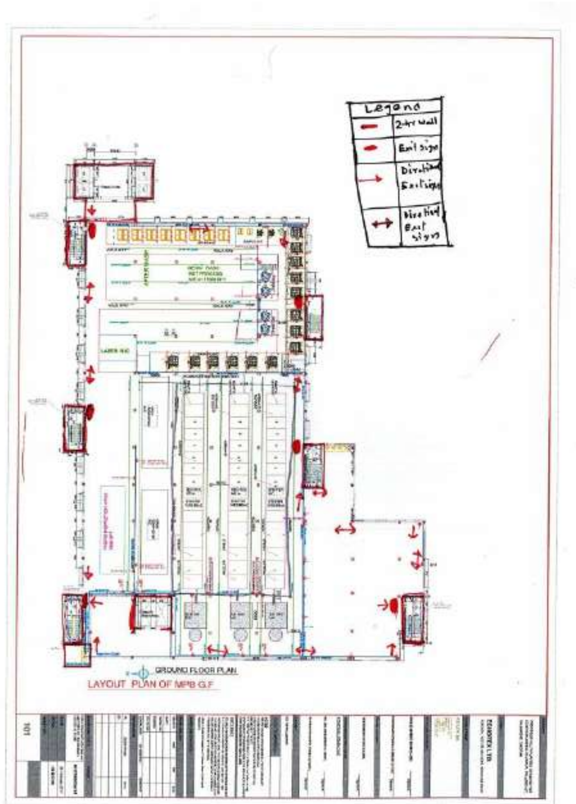
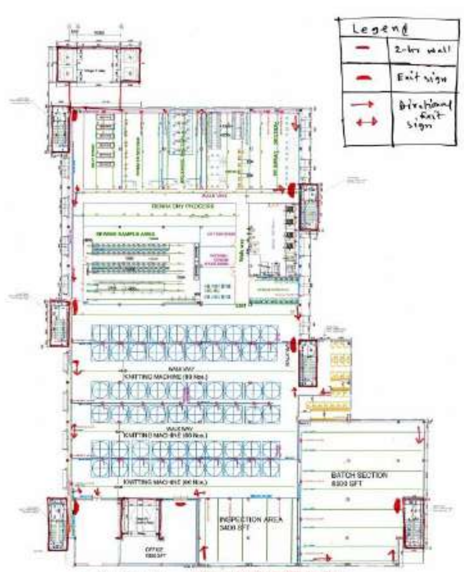
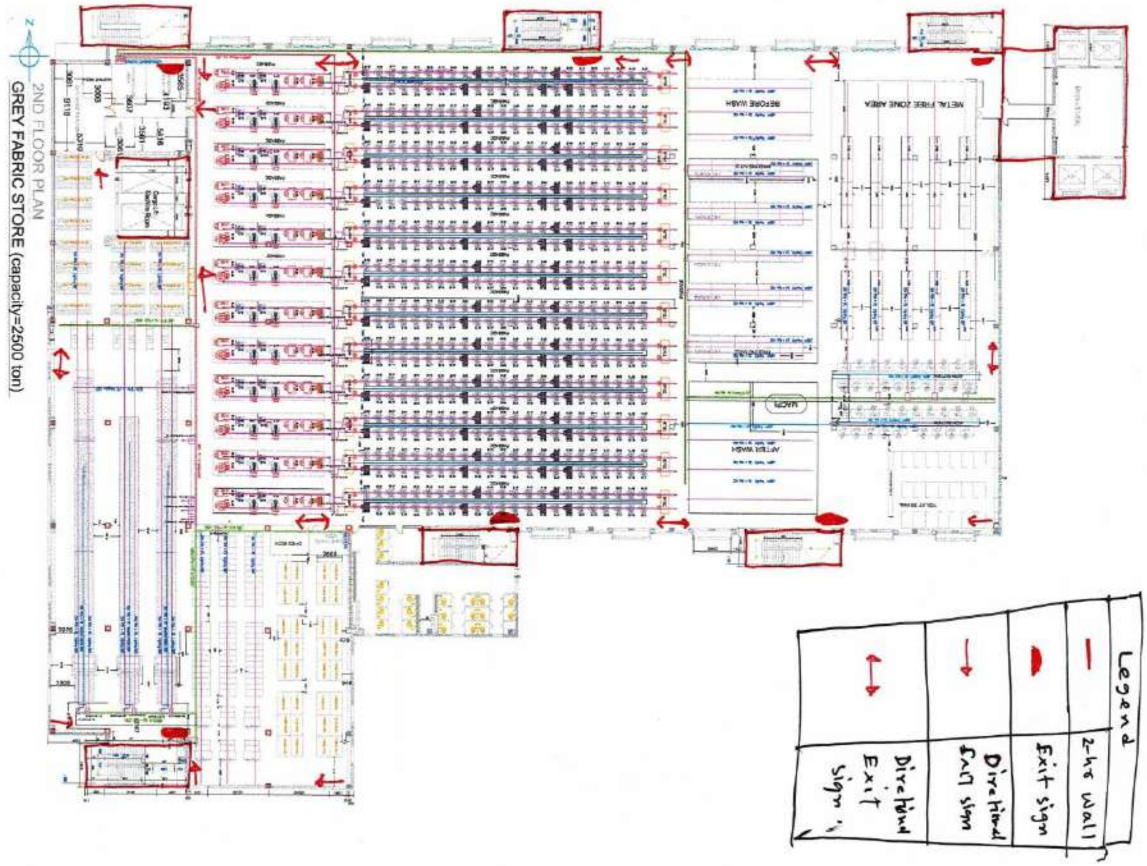


Fig: Ground floor exits plan.




2ND FLOOR PLAN
GREY FABRIC STORE (capacity=2500 ton)
BEFORE WASH
METAL FREE ZONE AREA
AFTER WASH
Legend
2-hr wall
Exit sign
Directional Exit sign
Directional Exit sign

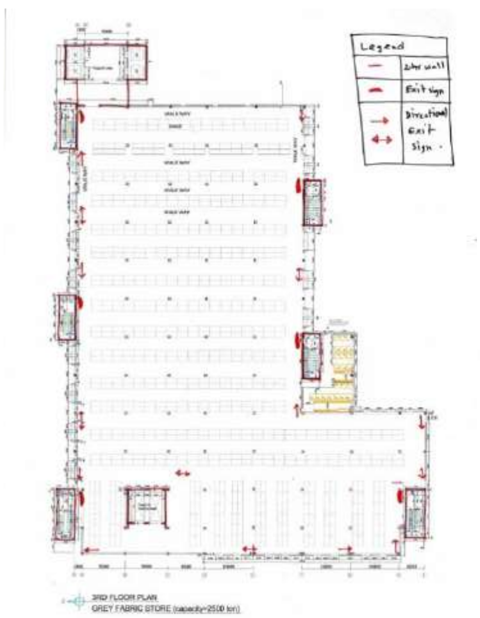


Fig: 5th floor exits signs.

Employees evacuating the building through the **<u>front three exits</u>** will muster at **Muster Point A** at the south side of the open field.

Employees evacuating the building through the **<u>Backside three</u>** exits will muster at **Muster Point C** at the north side before the public high way of B.

Employees evacuating from all six exits can reach public way and ultimately public high way point B.

8.19 Confidential Form

<u>**Complete Appendix 3 and send it to the MPB Building Security Manager**</u>

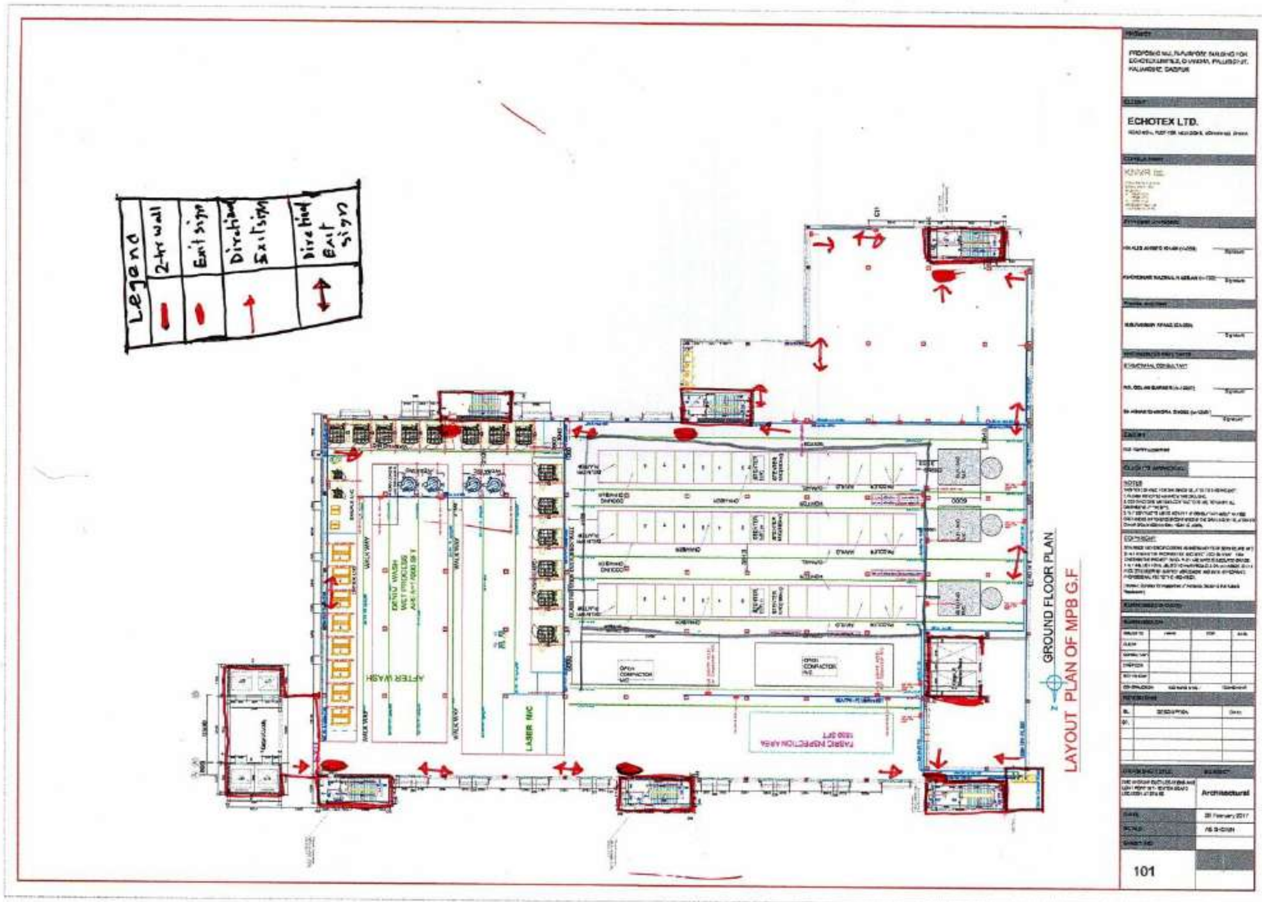
Employee's Name: ____

Building – North or South

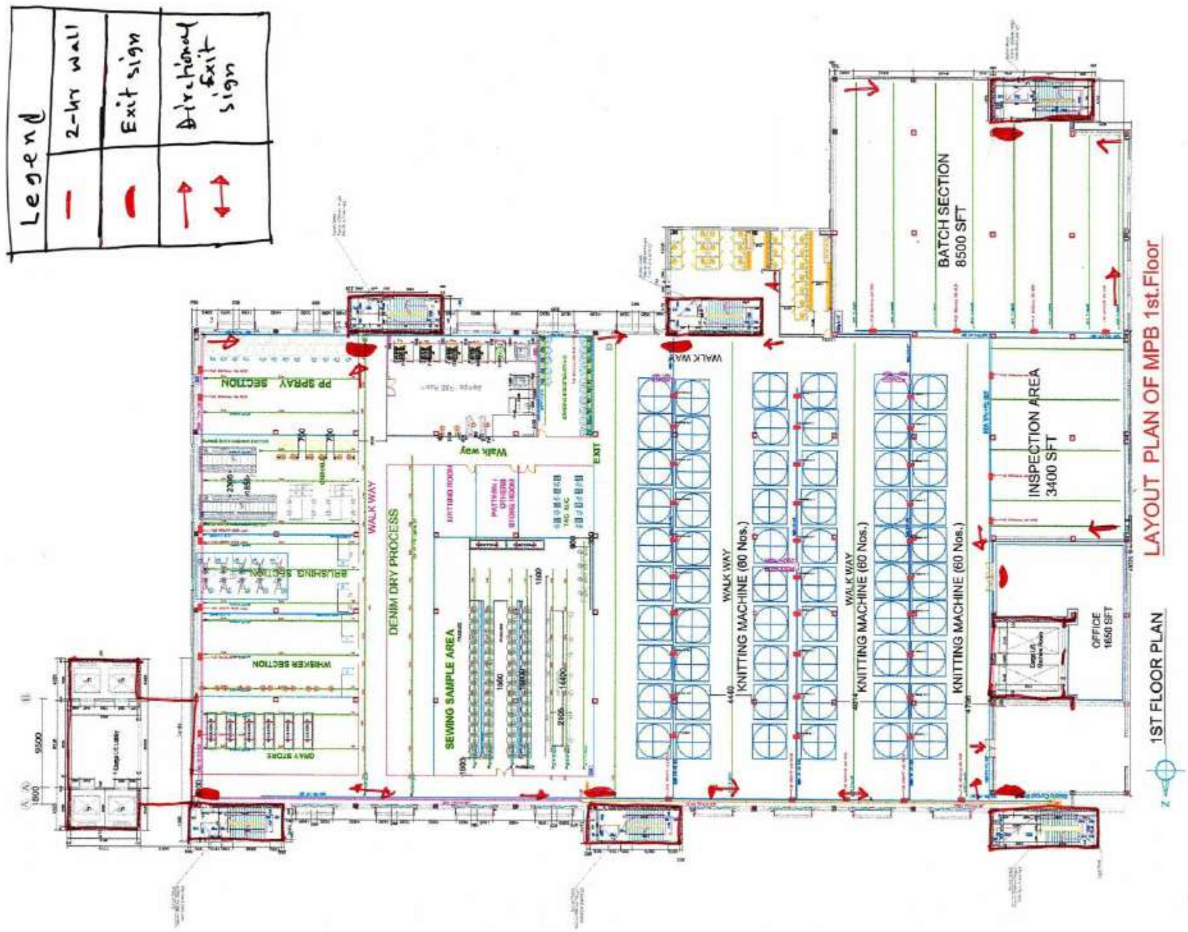
Floor Number- G-1-2-3-4-5

Nature of Mobility Impairment: ________________________________

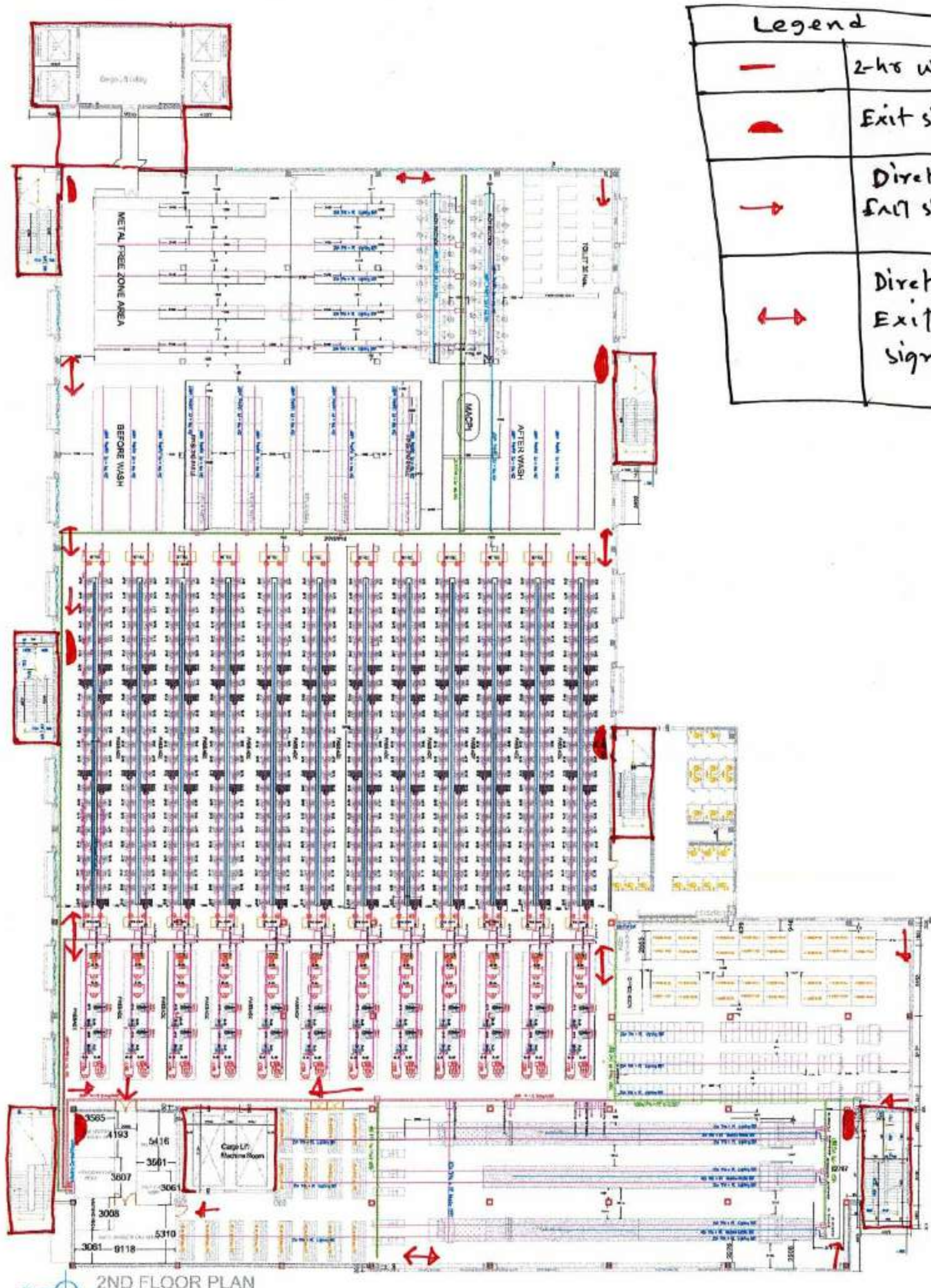
Appendix-1: Fire Rated Barriers & Exit Signs



Legend
2-hr wall
Exit sign
Directional Exit sign
Directional Exit sign
ECHOTEX LTD.
GROUND FLOOR PLAN
LAYOUT PLAN OF MPB G.F
AFTER WASH
LASER M/C
FABRIC INSPECTION AREA
Architectural
101



Legend
2-hr wall
Exit sign
Directional Exit sign
LAYOUT PLAN OF MPB 1st.Floor
1ST FLOOR PLAN
BATCH SECTION
8500 SFT
INSPECTION AREA
3400 SFT
OFFICE
1650 SFT
KNITTING MACHINE (60 Nos.)
KNITTING MACHINE (60 Nos.)
KNITTING MACHINE (60 Nos.)
WALK WAY
WALK WAY
WALK WAY
WALK WAY
DENIM DRY PROCESS
SEWING SAMPLE AREA
PP SPRAY SECTION
BRUSHING SECTION
WHISKER SECTION
GRAY STORE
Walk way
EXIT



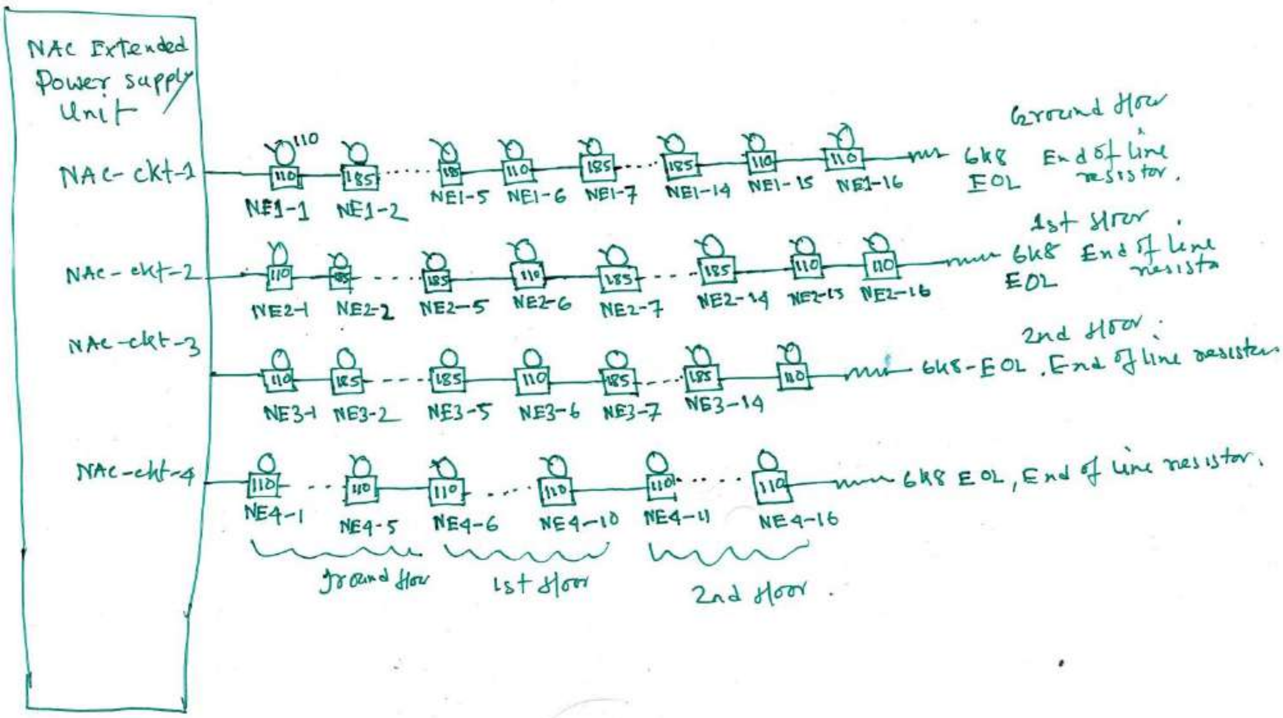
2ND FLOOR PLAN

GREY FABRIC STORE (capacity=2500 ton)

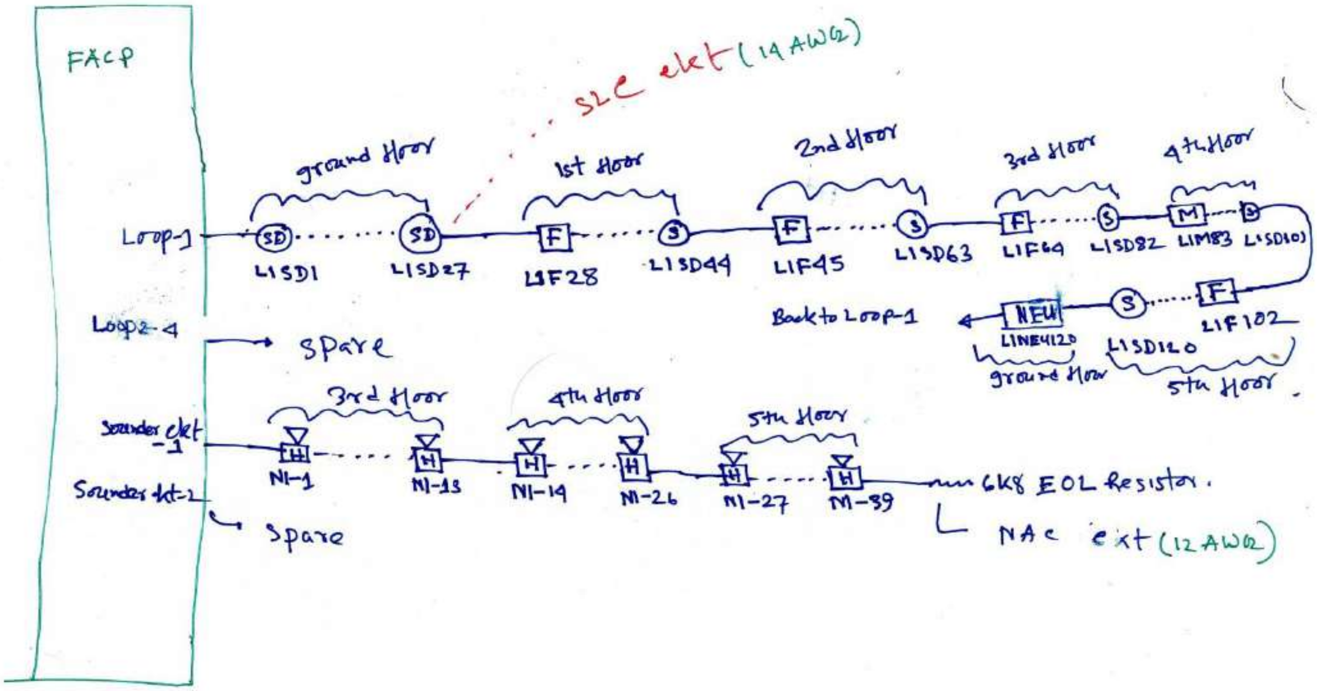
Legend	
	2-hr wall
	Exit sign
	Directional Exit sign
	Directional Exit sign

3RD FLOOR PLAN
GREY FABRIC STORE (capacity=2500 ton)

Appendix-2: Fire Alarm System

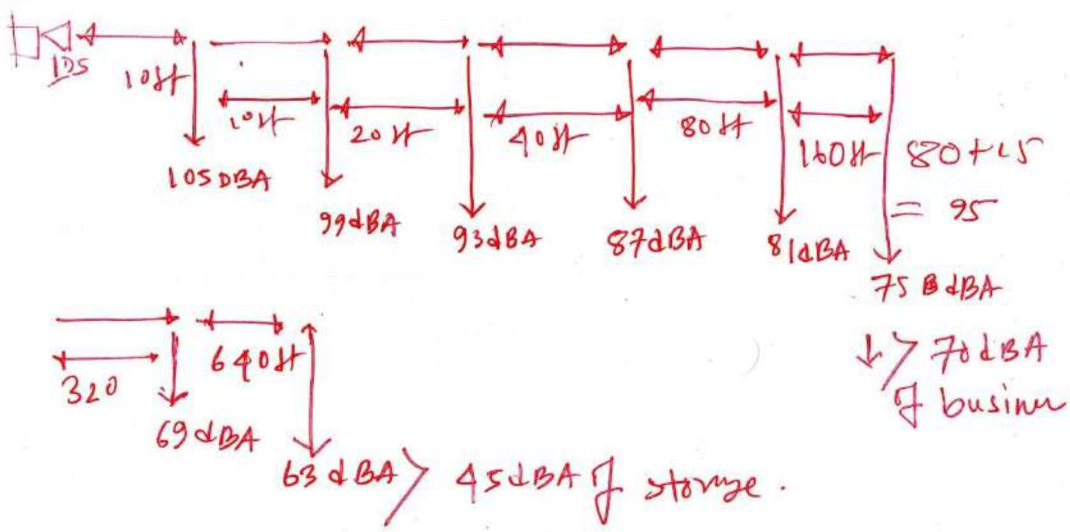


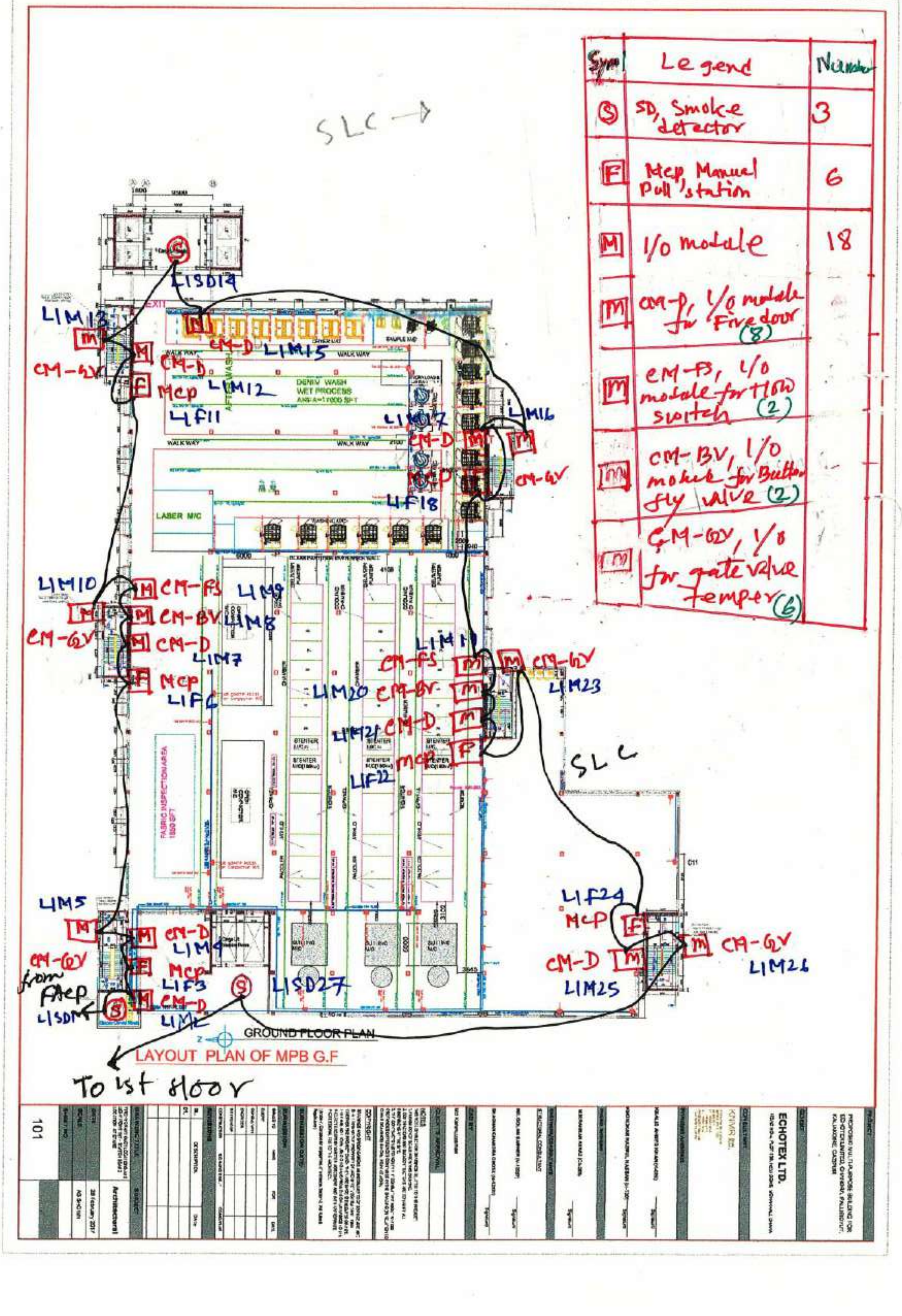
Riser diagram of NAC Extended sounder ckt.



Riser diagram

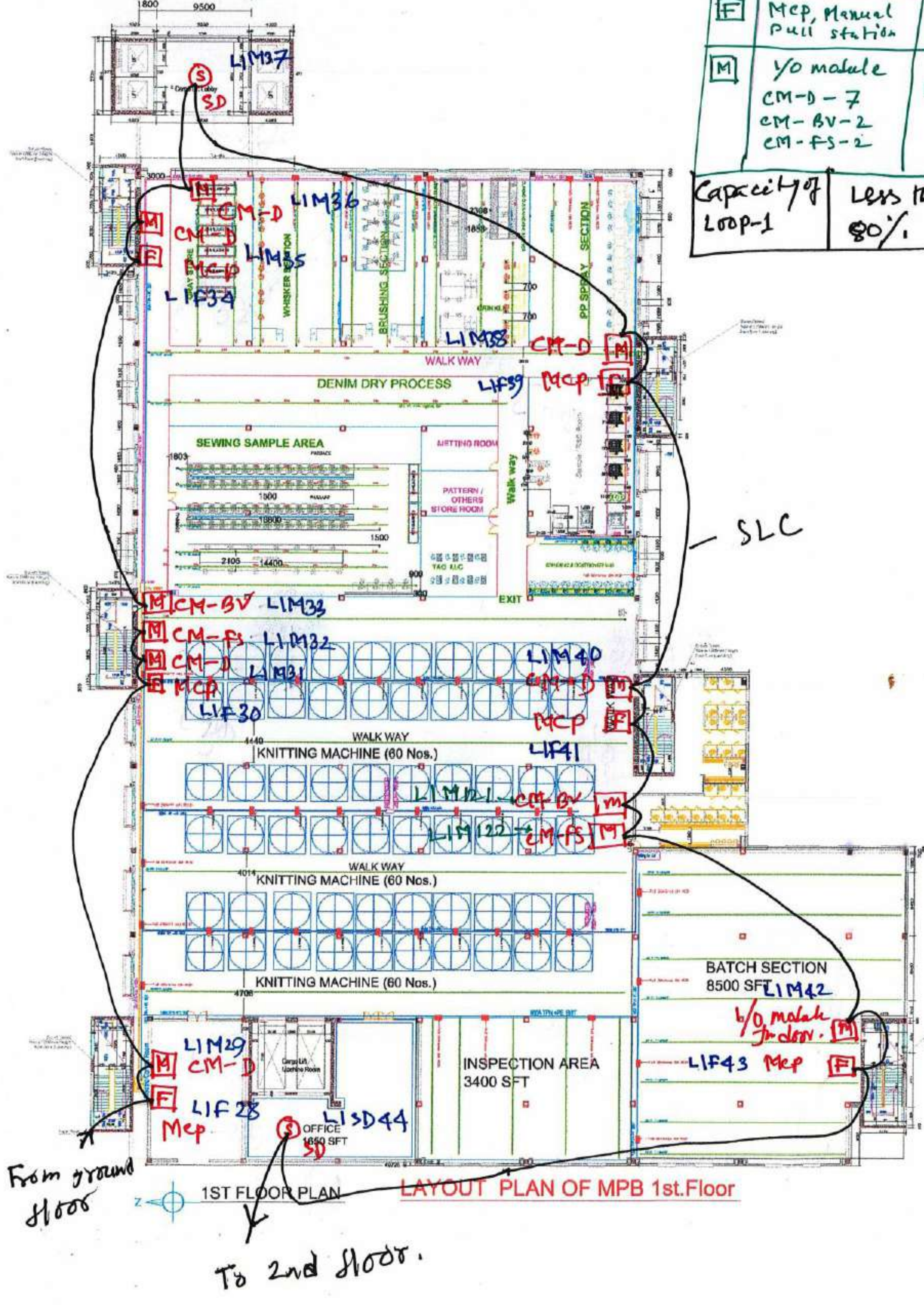
For Business = 55 + 15 = 70 dBA
Storage = 30 + 15 = 45 dBA
Industrial = 80 + 15 = 95 dBA



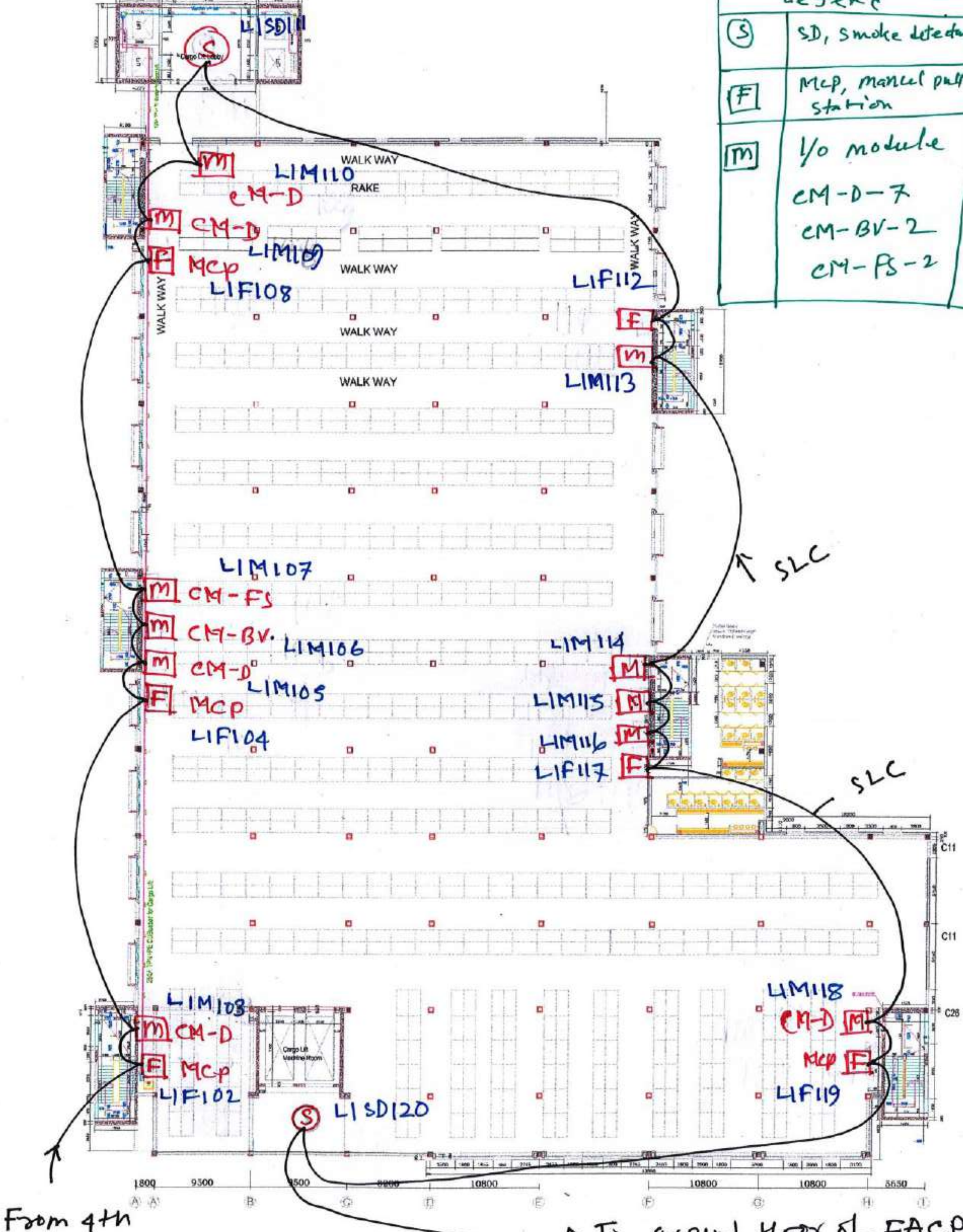

Sym
Legend
Number
SD, Smoke detector
3
Mcp Manual Pull station
6
I/O module
18
CM-D, I/O module for Fire door (8)
CM-FS, I/O module for Flow switch (2)
CM-BV, I/O module for Butterfly valve (2)
CM-GV, I/O for gate valve temper (6)
SLC
LISD14
LIM13
CM-GV
CM-D
LIM15
LIM12
Mcp
LF11
DENIM WASH WET PROCESS
WALK WAY
LABER M/C
LIM16
LIM17
CM-D
MCP
LF18
CM-GV
LIM10
CM-FS
LIM9
CM-BV
LIM8
CM-D
LIM7
Mcp
LIF6
LIM19
CM-FS
CM-GV
LIM23
LIM20
CM-BV
LIM21
CM-D
LIF22
Mcp
SLC
FABRIC INSPECTION AREA
LIF24
MCP
CM-D
LIM25
CM-GV
LIM26
LIM5
CM-D
LIM4
CM-GV
from FACP
Mcp
LIF3
LISD27
LISD1
CM-D
LIM2
GROUND FLOOR PLAN
LAYOUT PLAN OF MPB G.F
To 1st floor
ECHOTEX LTD.
Architectural
101

Sym	Legend	Number
(S)	SD Smoke detector	2
[F]	MCP, Manual Pull station	6
[M]	I/O module CM-D - 7 CM-BV-2 CM-FS-2	11

Capacity of Loop-1	Less than 80%.

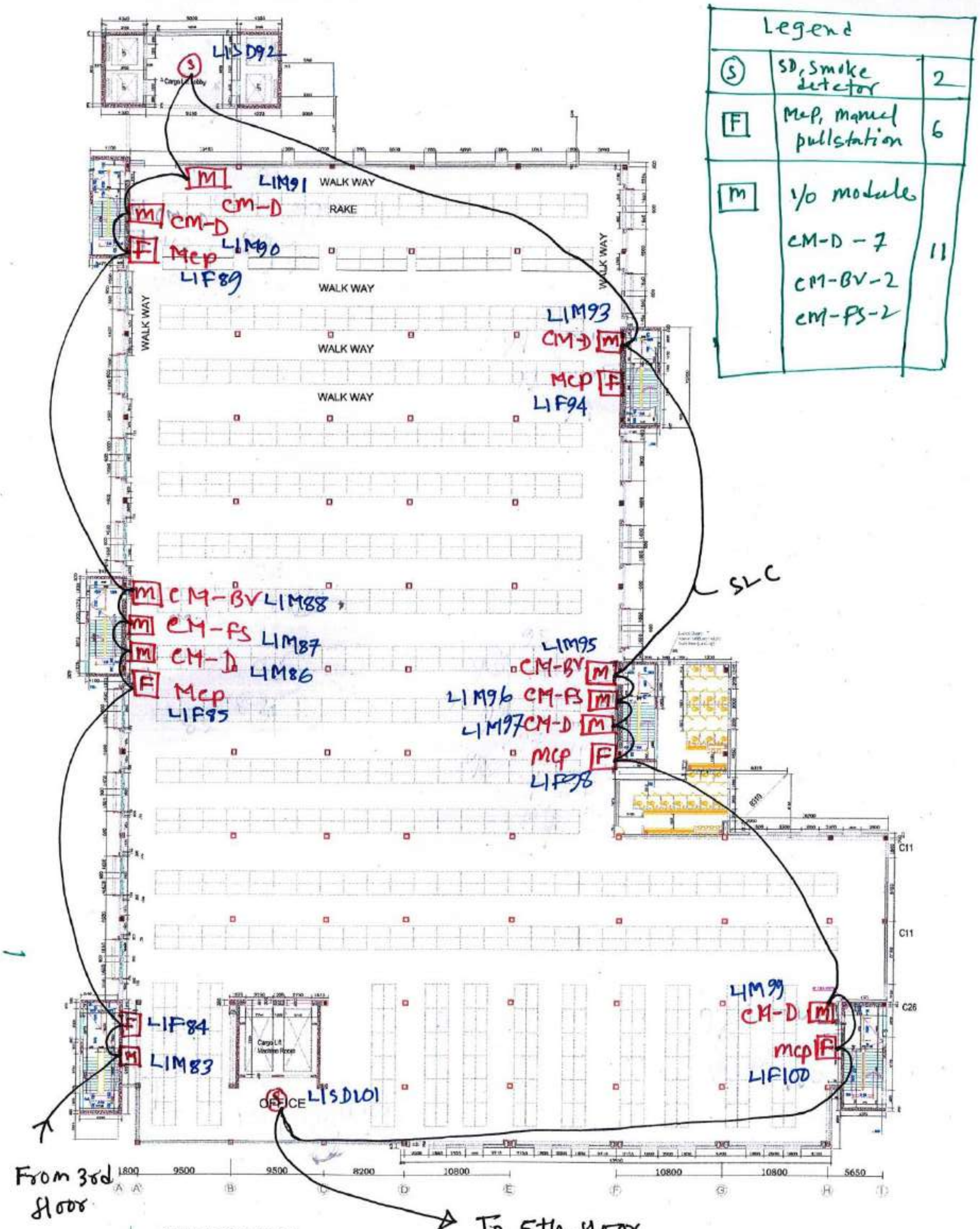


Legend		
S	SD, Smoke detector	2
F	MCP, manual pull station	6
M	I/O module CM-D-7 CM-BV-2 CM-FS-2	11



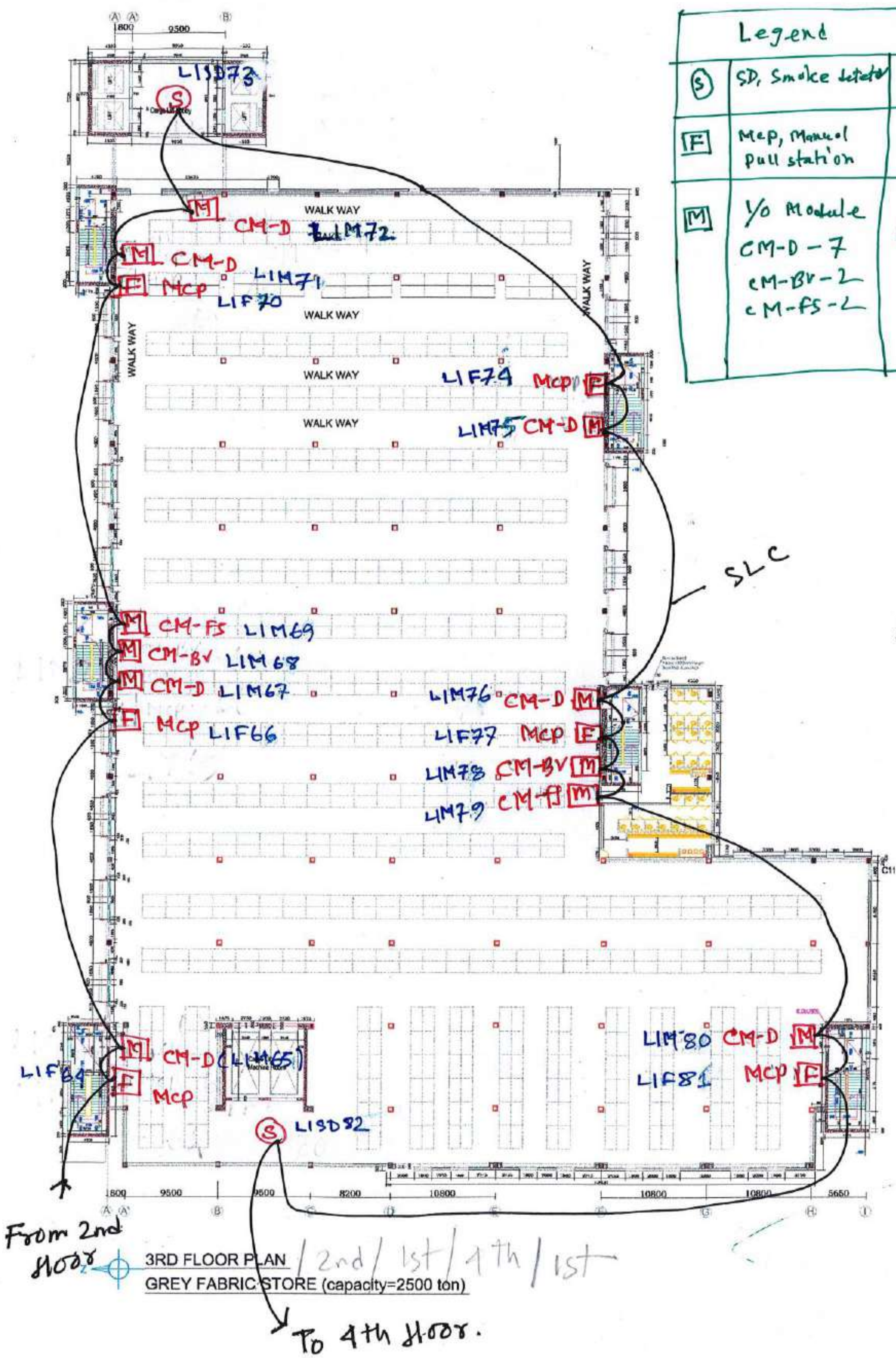
5TH FLOOR PLAN

FINISHED FABRIC /HANGER/CARTON STORE (capacity=2500 ton)

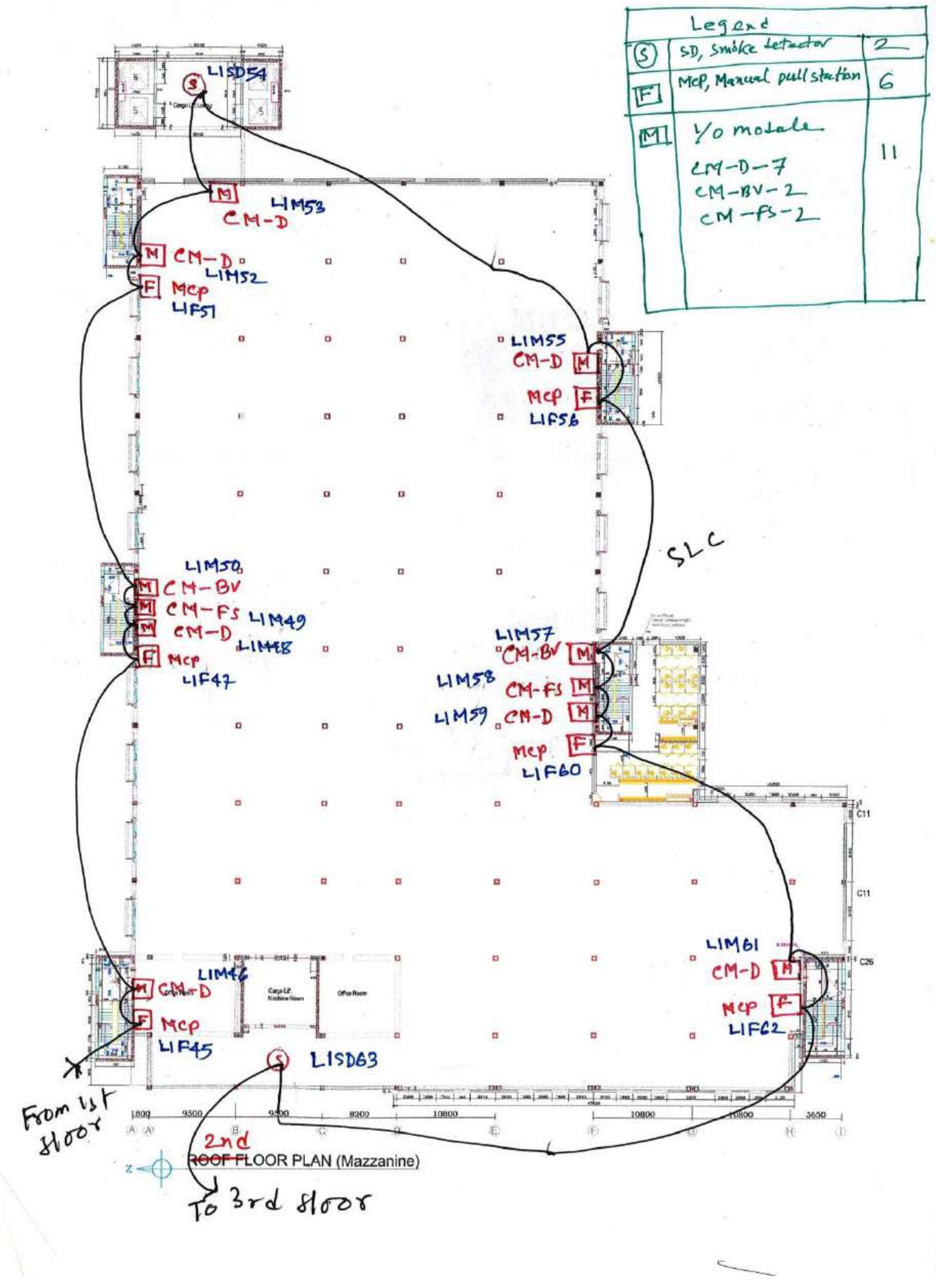


4TH FLOOR PLAN

YARN STORE (capacity=2500 ton)



Legend		
S	SD, Smoke detector	2
F	Mcp, Manual pull station	6
M	I/O Module CM-D – 7 CM-BV – 2 CM-FS – 2	11

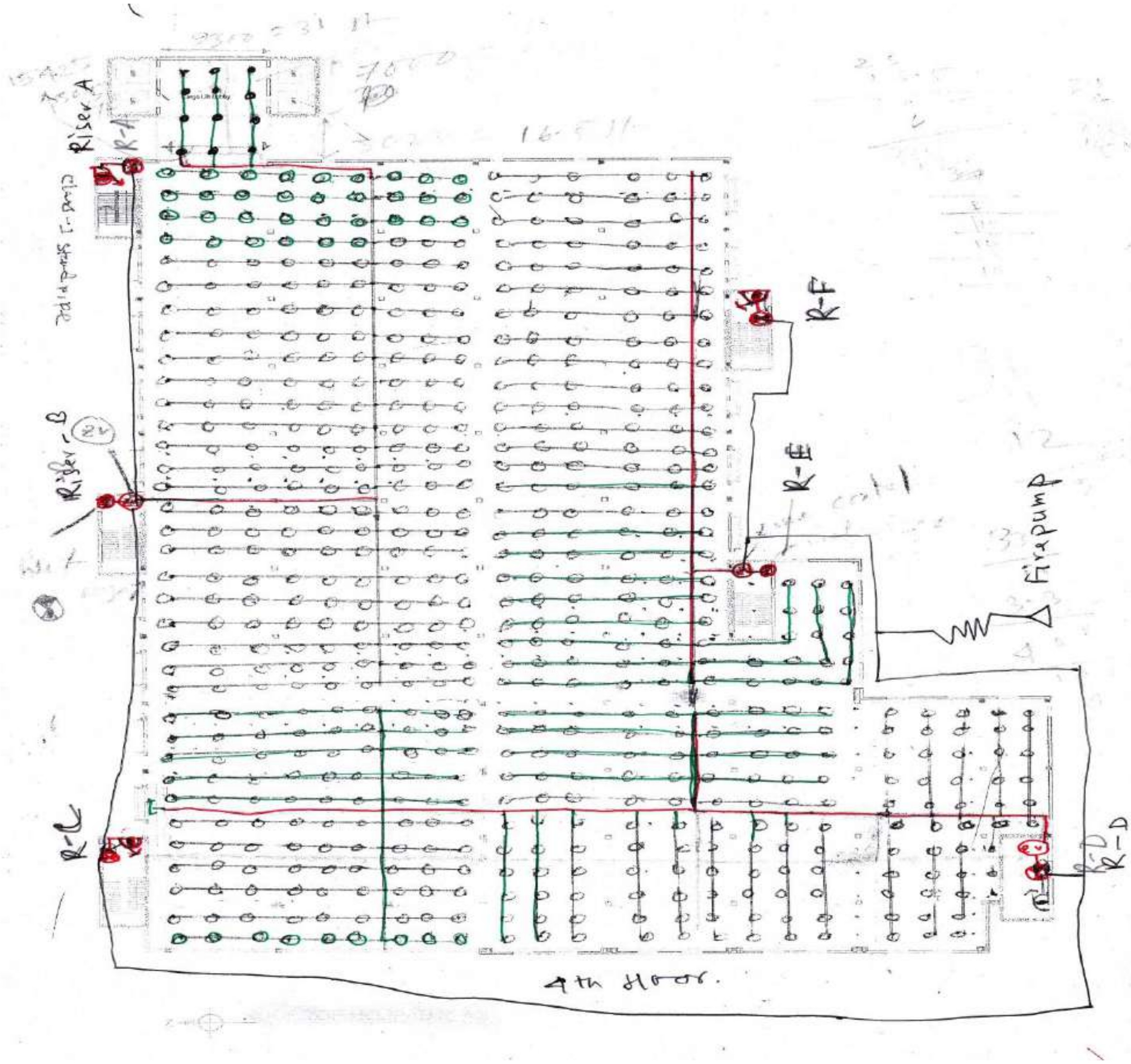


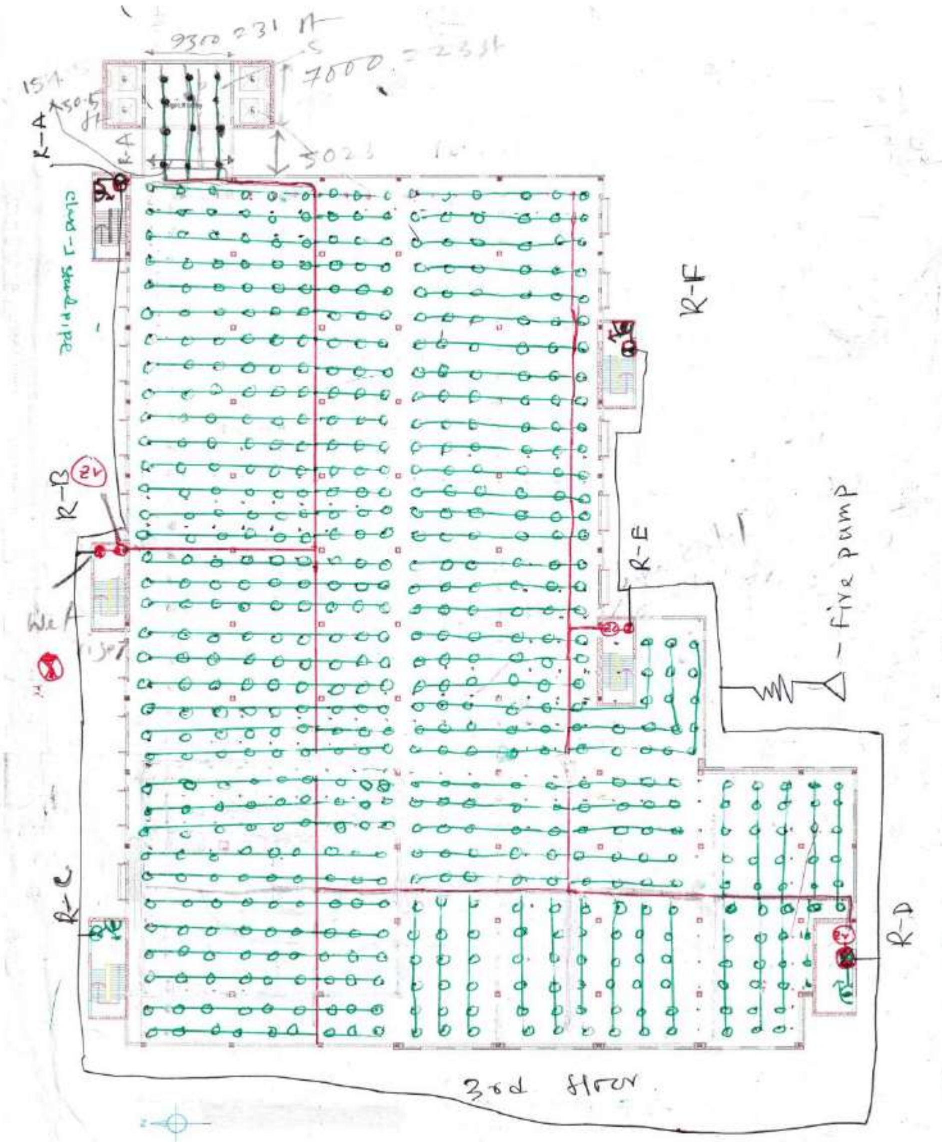
Legend
S | SD, Smoke detector | 2
F | MCP, Manual pull station | 6
M | I/O module | 11
CM-D-7
CM-BV-2
CM-FS-2
L1SD54
Cargo Lift Lobby
M L1M53 CM-D
M CM-D L1M52
F MCP L1F51
L1M55 CM-D M
MCP F L1F56
SLC
L1M50 M CM-BV
M CM-FS L1M49
M CM-D L1M48
F MCP L1F47
L1M57 CM-BV M
L1M58 CM-FS M
L1M59 CM-D M
MCP F L1F60
C11
C11
L1M61 CM-D M
C26
MCP F L1F62
L1M46 M CM-D
Cargo Lift Machine Room
Office Room
F MCP L1F45
S L1SD63
From 1st floor
1800 9500 9500 8200 10800 10800 10800 3650
2nd
ROOF FLOOR PLAN (Mazzanine)
To 3rd floor

	System inputs	A: Actuate common alarm signal indicator	B: Actuate audible alarm signal	C: Actuate common supervisory signal	D: Actuate audible supervisory signal	E: Actuate trouble signal	F: Actuate audible trouble signal	G: Actuate alarm indicator	H: Transmit fire signal to supervisory station	I: Supervisory signal to sup. station	J: Trouble signal to supervising station	K: Actuate exterior strobe at region point	
1	MCP	●	●					●	●				
2	Smoke detector	●	●					●	●				1
3	FACP AC power failure					●	●						2
4	Fire alarm system low battery					●	●					●	3
5	Open circuit					●	●					●	4
6	Ground fault					●	●					●	5
7	NAC ckt short					●	●					●	6
8	Spk alarm valve (I/O module)	●	●					●	●				7
9	tamper switch (I/O module)					●	●					●	8
		A	B	C	D	E	F	G	H	I	J	K	
		Control unit annunciation							Notification			supplementary	

Fire alarm operational Matrix

Appendix-3: Fire Protection System





Sprinklered building 1000 gpm.

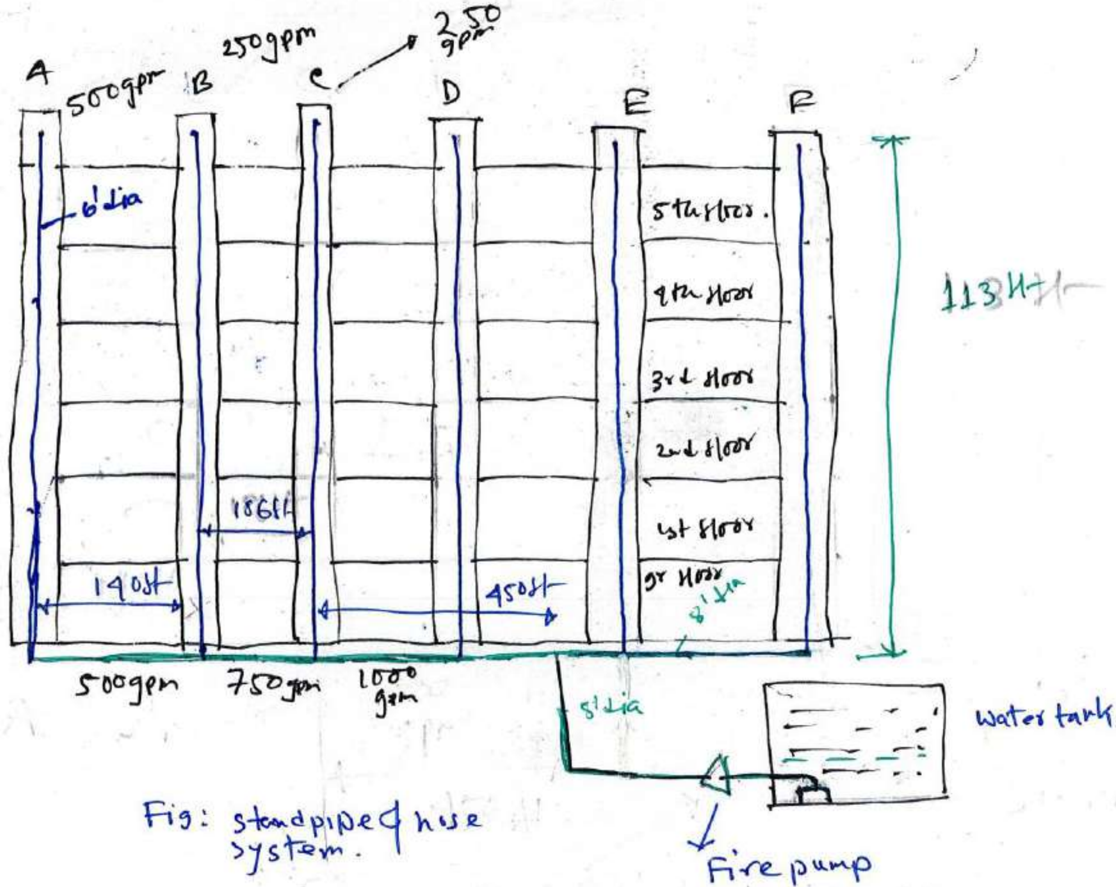
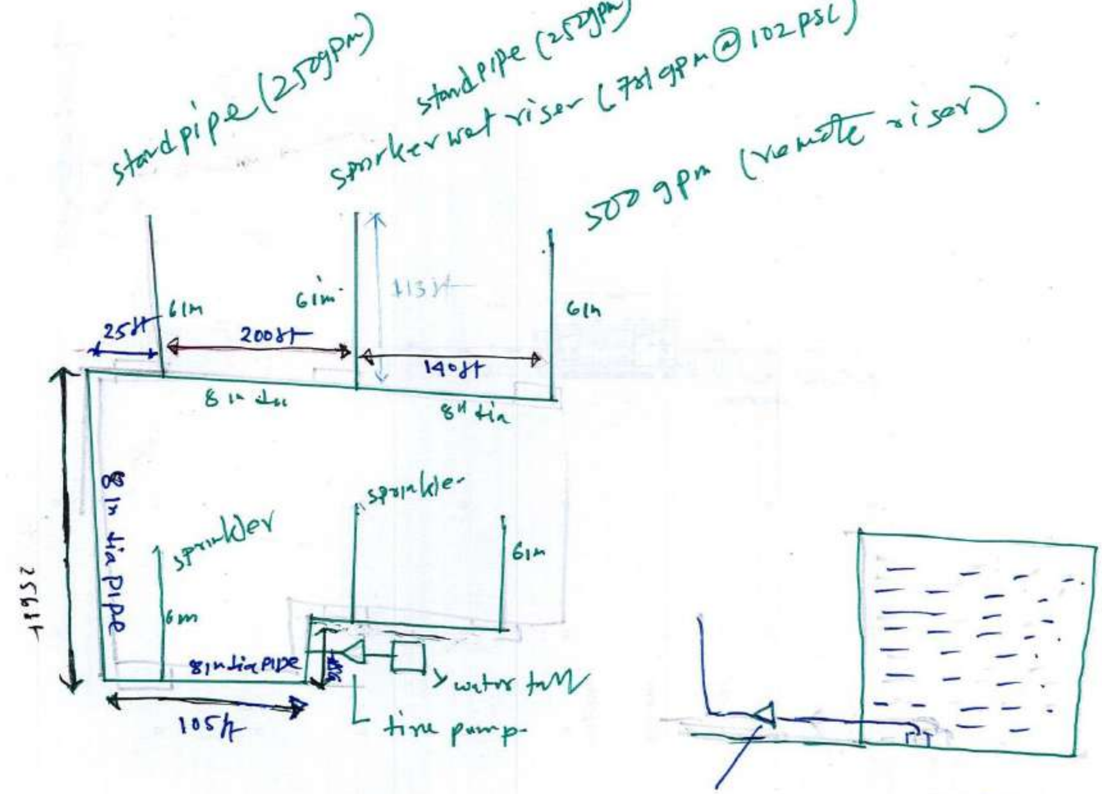


Fig: standpipe & hose system.

Fire pump capacity = 1000 gpm
Head = 175 psi
Positive suction as H. split case.



Fire pump 1000gpm @ 175 psi

Fig: Fire protection — riser diagram.

Water tank capacity
= 60x1000 gpm
= 60,000 gallons

\

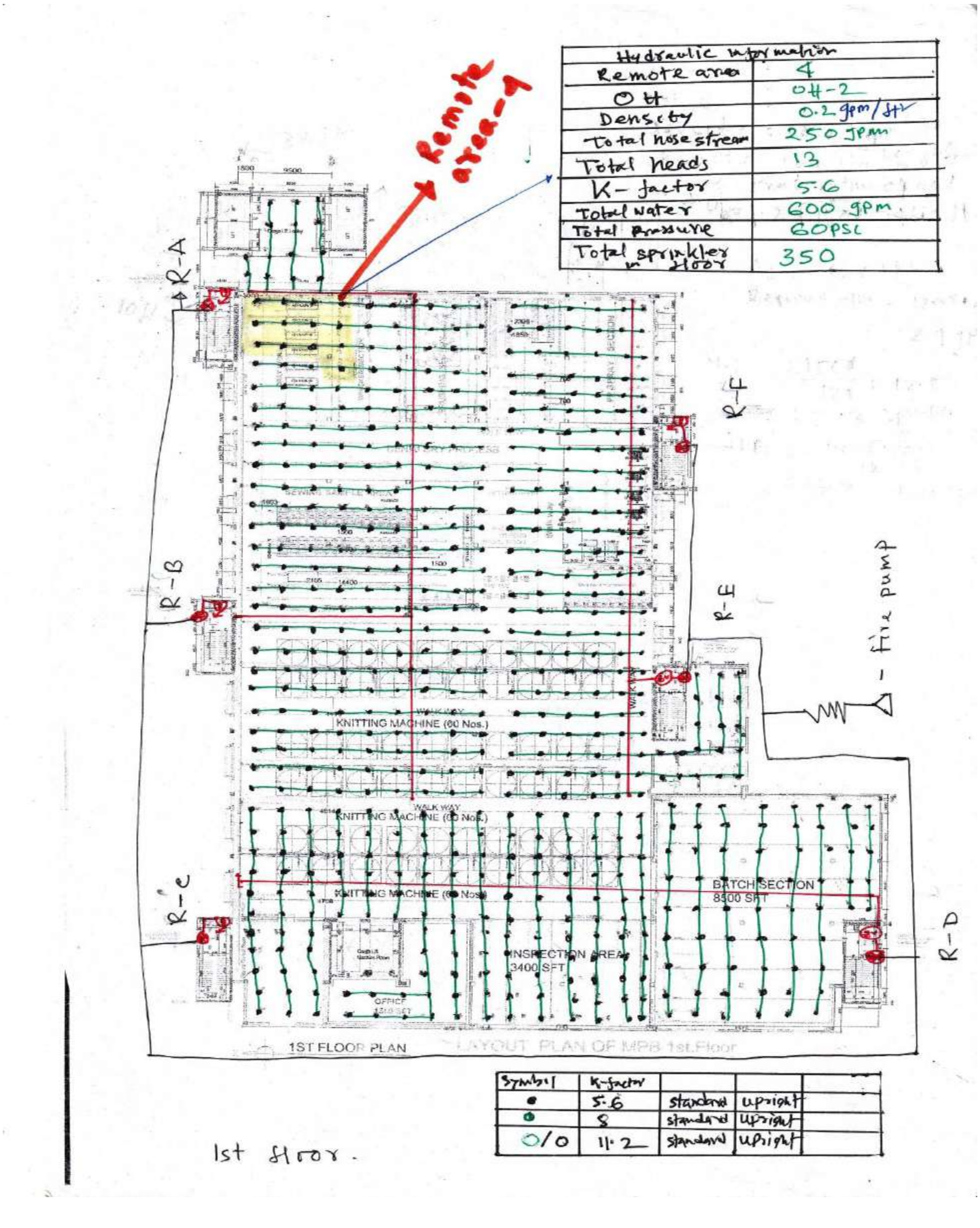
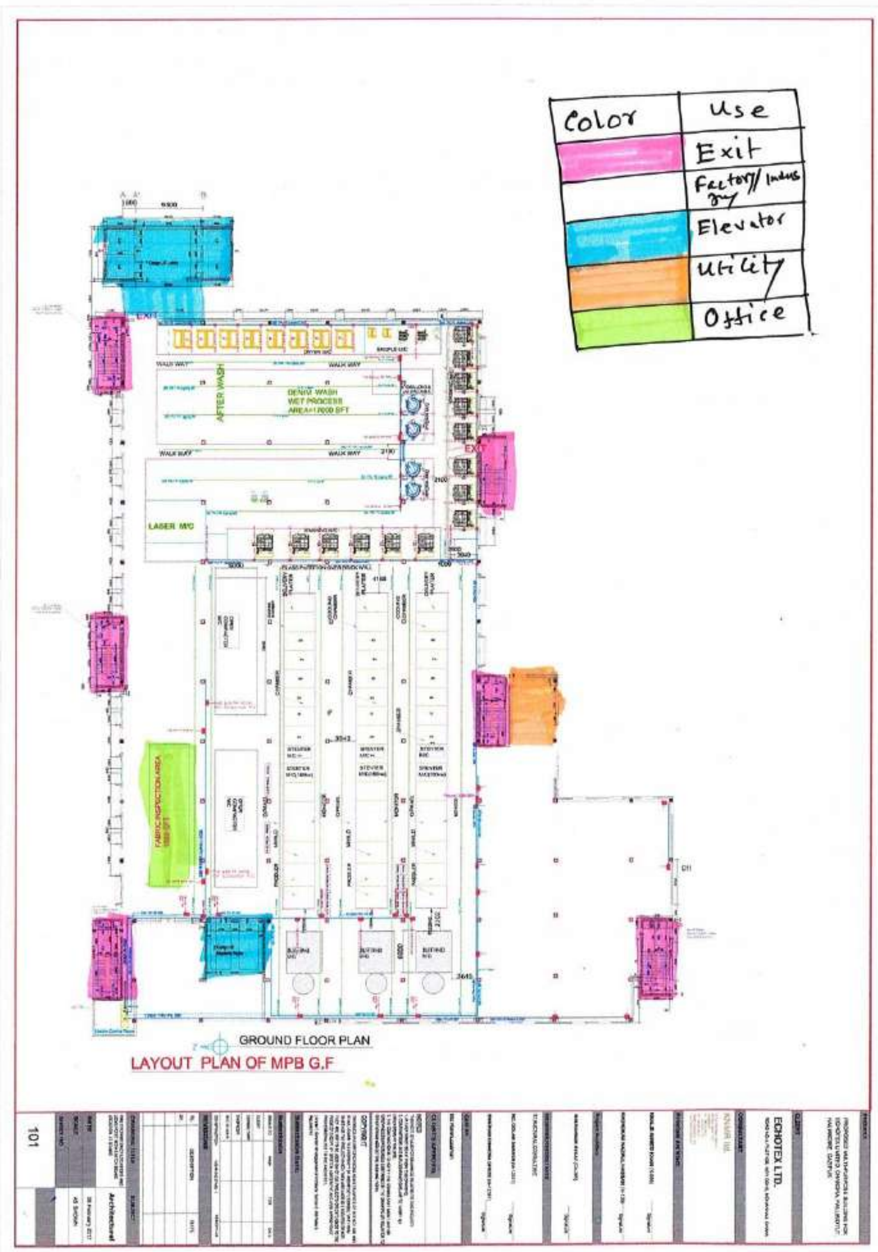


Fig: 1st Floor Plan.

Appendix-4: Building Occupancy



Color	Use
	Vertical Exit
	Factory/Industry
	Elevator
	Utility
	Storage
	Office

4TH FLOOR PLAN

YARN STORE (capacity=2500 ton)

Color	Use
(pink)	Vertical Exit
(white)	Factory / Industry
(blue)	Elevator
(orange)	Utility
(yellow)	storage

3RD FLOOR PLAN

GREY FABRIC STORE (capacity=2500 ton)

Color	Use
	Vertical Exit
	Factory/ Industry
	Elevator
	Utility
	Office

3RD FLOOR PLAN
GREY FABRIC STORE (capacity=2500 ton)

5TH FLOOR PLAN

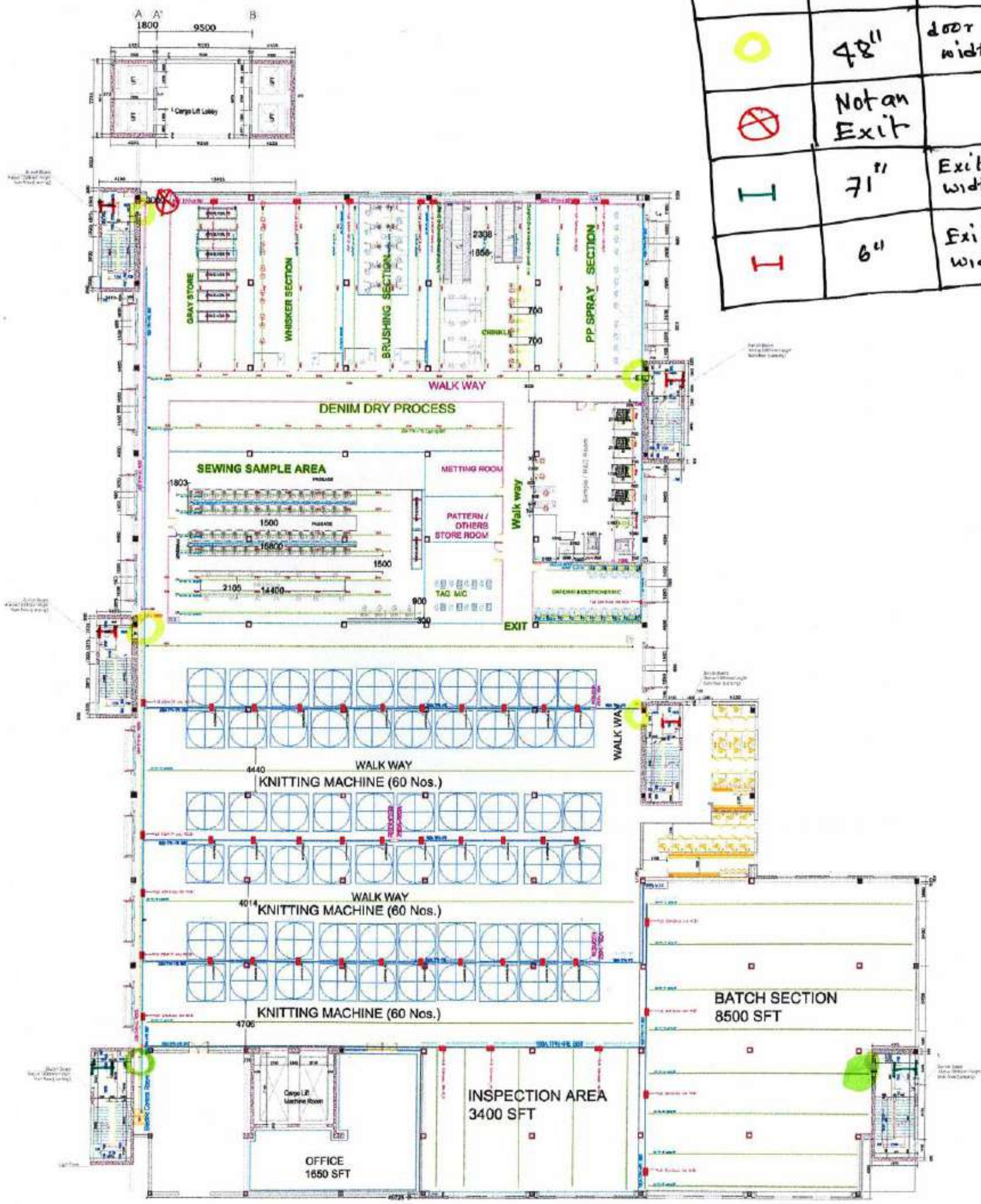
FINISHED FABRIC /HANGER/CARTON STORE (capacity=2500 ton)

LAYOUT PLAN OF MPB 1st.Floor
1ST FLOOR PLAN
INSPECTION AREA
3400 SFT
OFFICE
1650 SFT
BATCH SECTION
8500 SFT
KNITTING MACHINE (60 Nos.)
WALK WAY
KNITTING MACHINE (60 Nos.)
WALK WAY
KNITTING MACHINE (60 Nos.)
WALK WAY
EXIT
TAG M/C
PATTERN / OTHERS STORE ROOM
Walk way
METTING ROOM
SEWING SAMPLE AREA
DENIM DRY PROCESS
WALK WAY
PP SPRAY SECTION
BRUSHING SECTION
WHISKER SECTION
GRAY STORE
Color
Use
Exit
Factory/Industry
Elevator
utility
Office

Appendix 5: Exit Location & Sizes

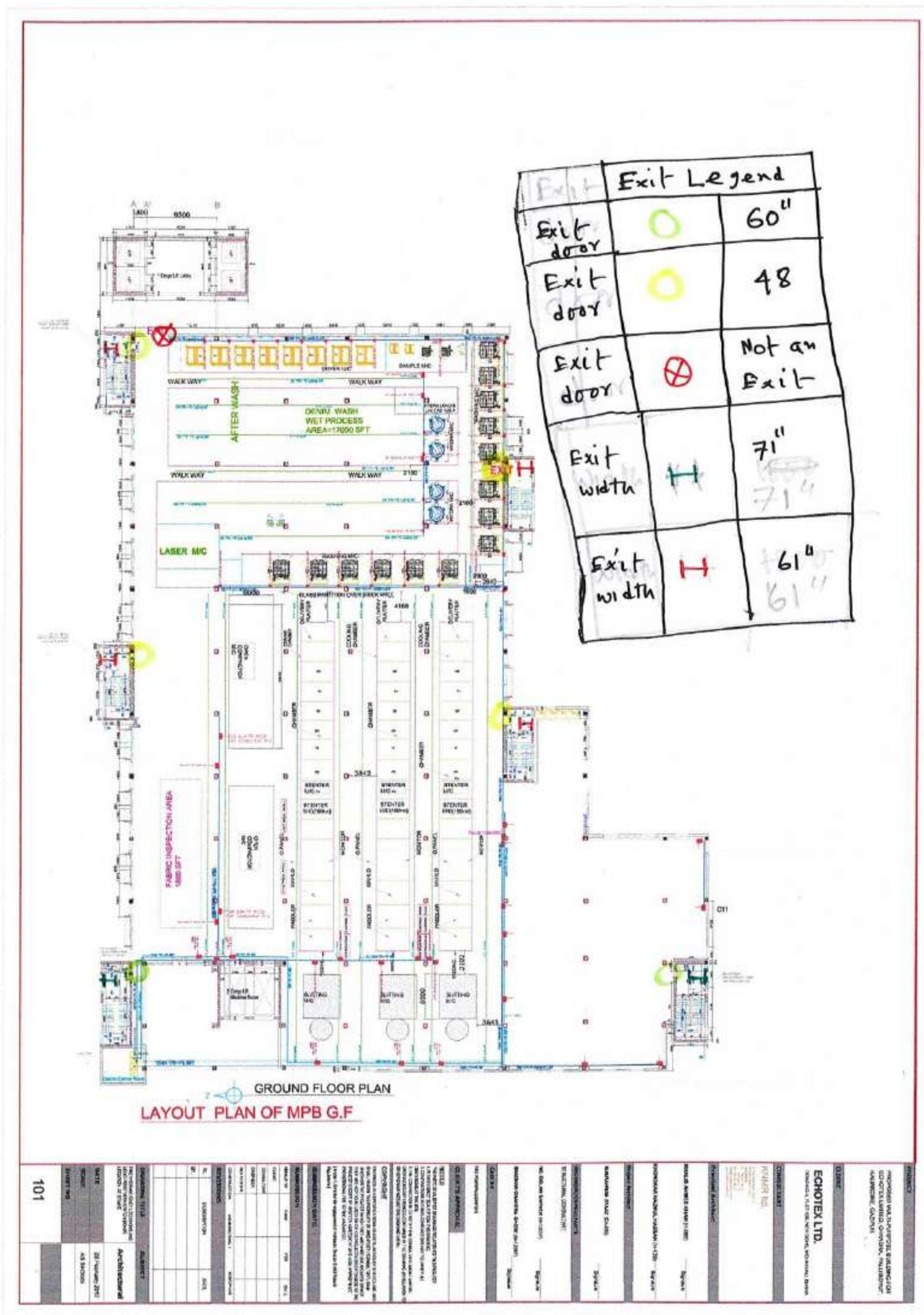
3RD FLOOR PLAN
GREY FABRIC STORE (capacity=2500 ton)

Exit Legend		Exit
	60"	Exit door width
	48"	door width
	Not an Exit	
	71"	Exit width
	6"	Exit width



1ST FLOOR PLAN

LAYOUT PLAN OF MPB 1st.Floor


Exit Legend
Exit door 60"
Exit door 48
Exit door Not an Exit
Exit width 71"
Exit width 61"
DENIM WASH WET PROCESS AREA=17000 SFT
AFTER WASH
WALK WAY
LASER M/C
FABRIC INSPECTION AREA
GROUND FLOOR PLAN
LAYOUT PLAN OF MPB G.F
ECHOTEX LTD.
101

Exit Legend	
	60"
	48"
	Not an Exit
	71"
	61"

4TH FLOOR PLAN

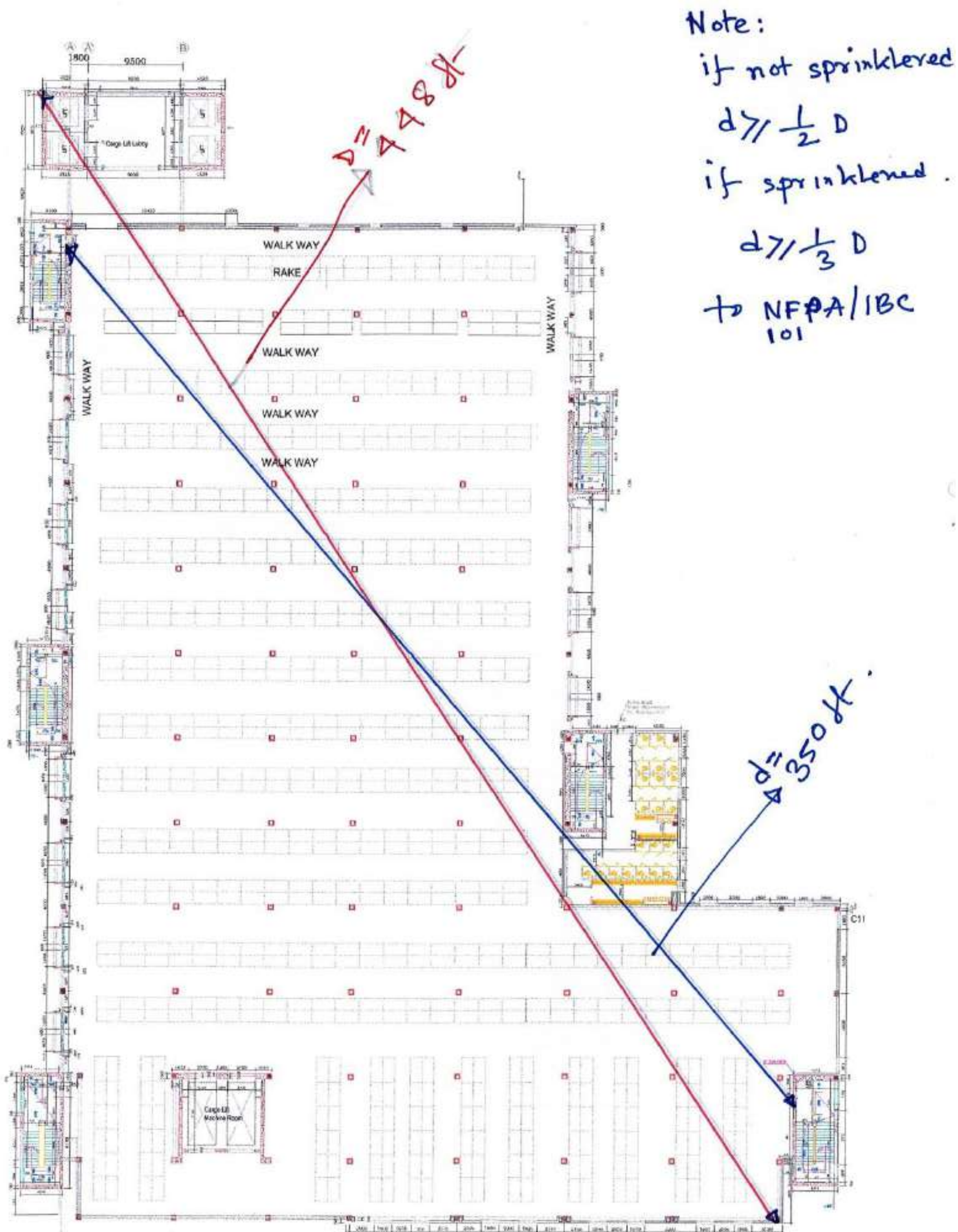
YARN STORE (capacity=2500 ton)

Exit Legend	
○	60"
○	48"
⊗	Not an Exit
⊢⊣	71"
⊢⊣	61"

5TH FLOOR PLAN

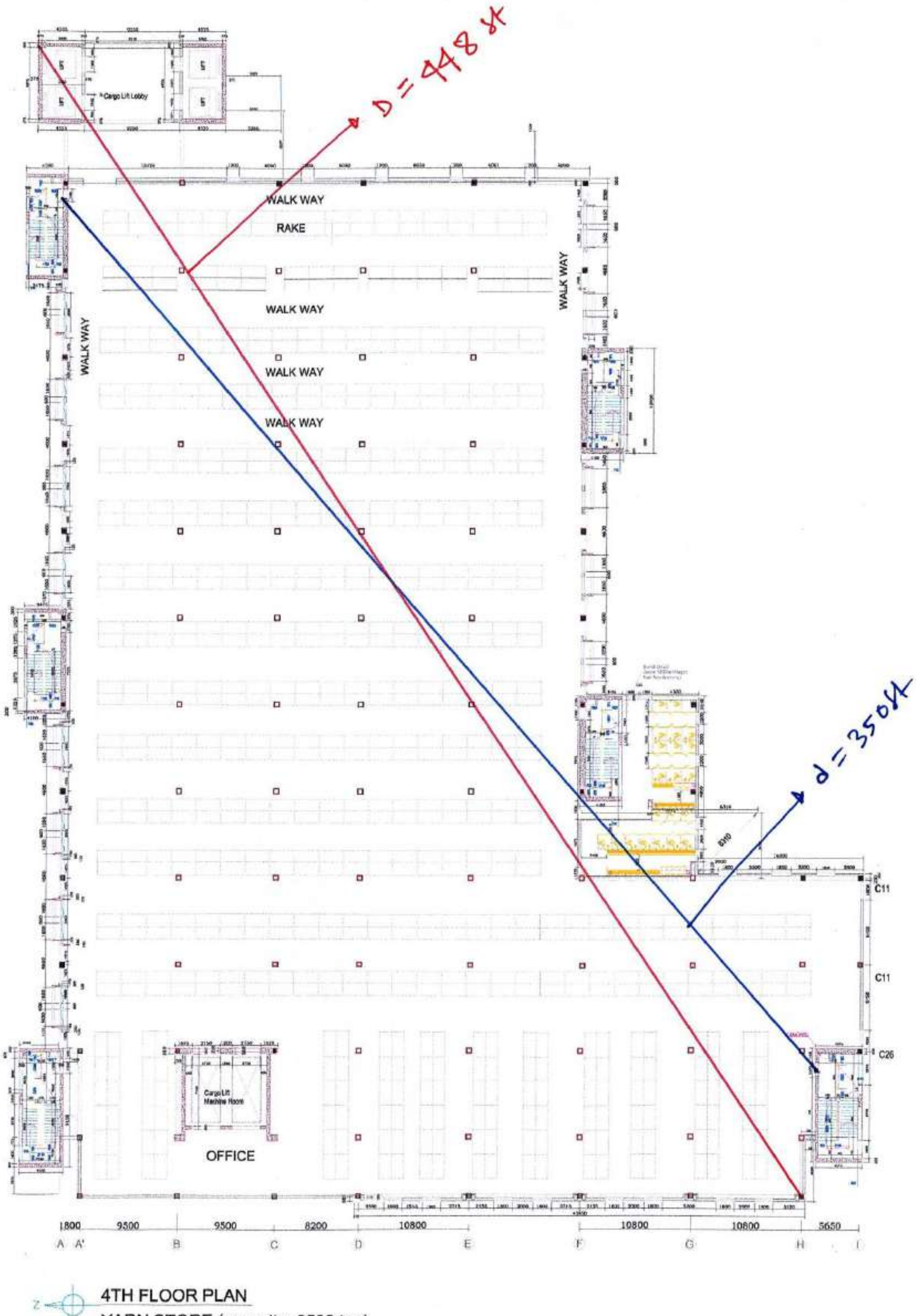
FINISHED FABRIC /HANGER/CARTON STORE (capacity=2500 ton)

Appendix-6: Exit Separation Distances



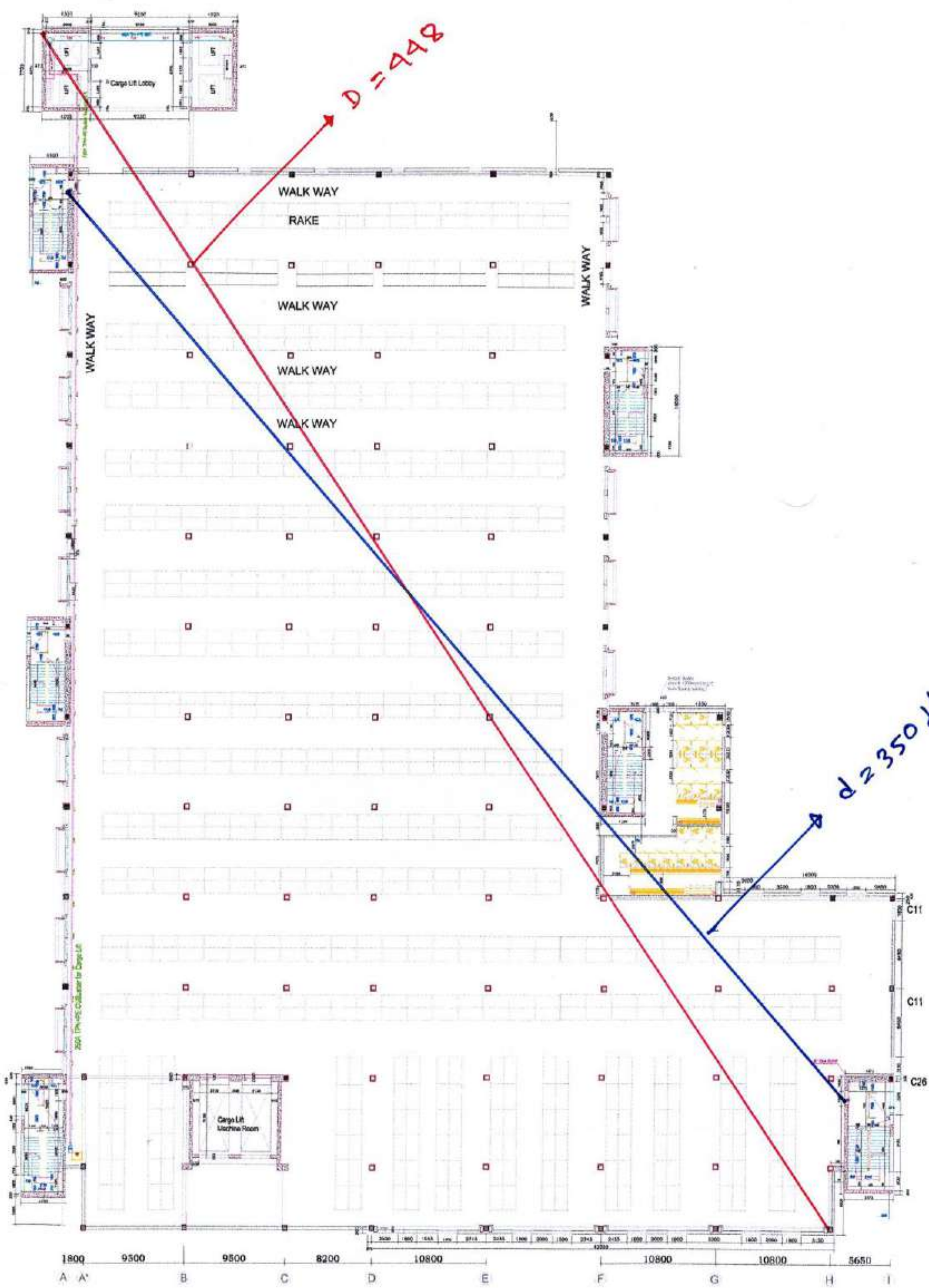
3RD FLOOR PLAN

GREY FABRIC STORE (capacity=2500 ton)

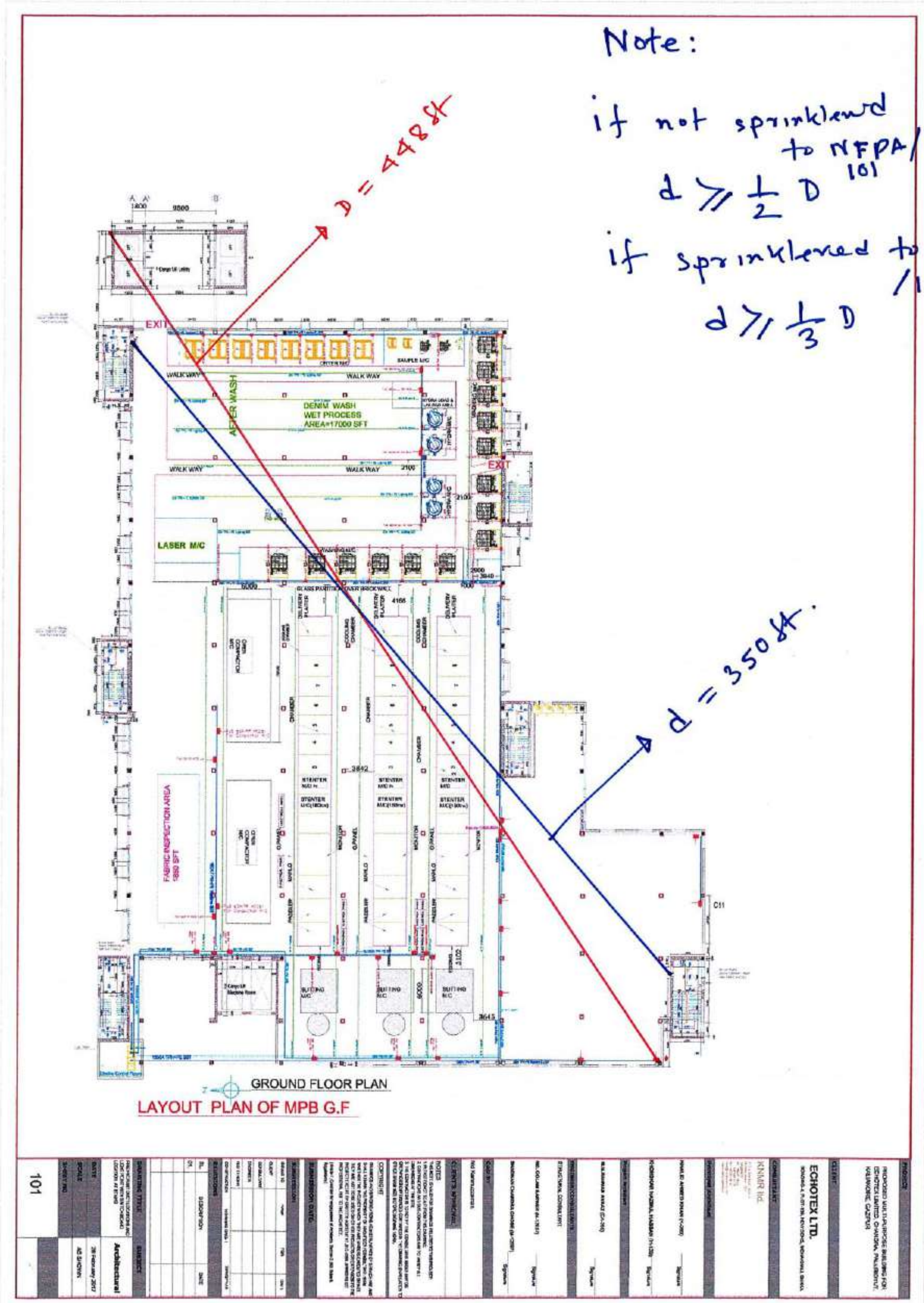


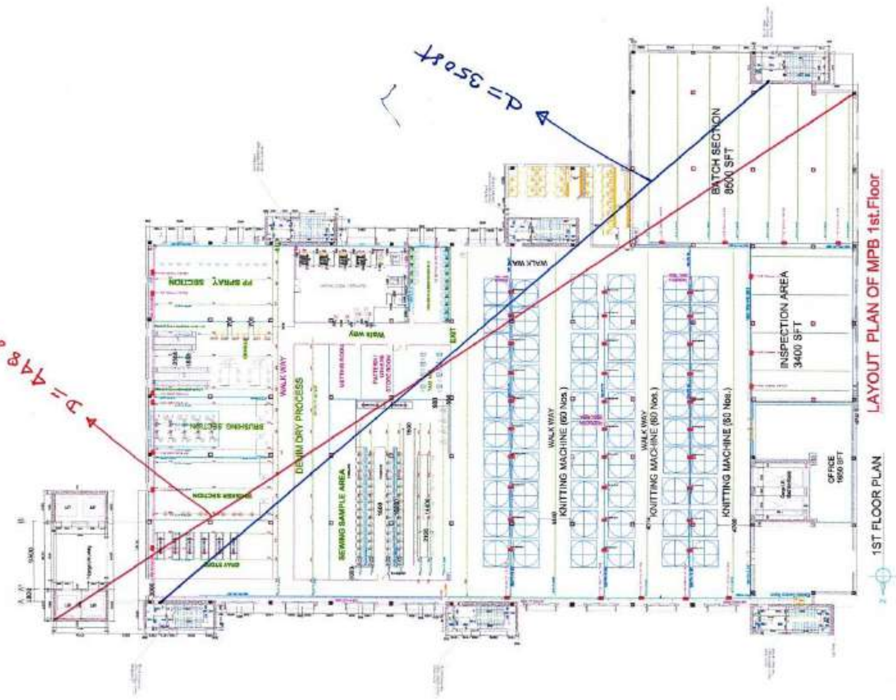
4TH FLOOR PLAN

YARN STORE (capacity=2500 ton)



5TH FLOOR PLAN
FINISHED FABRIC /HANGER/CARTON STORE (capacity=2500 ton)


Note:
if not sprinklerd to NFPA 101/IBC
d ≥ 1/2 D
if sprinklered to NFPA 101/IBC.
d ≥ 1/3 D
D = 448 ft
d = 350 ft.
EXIT
WALK WAY
AFTER WASH
DENIM WASH
WET PROCESS
AREA=17000 SFT
LASER M/C
FABRIC INSPECTION AREA
1880 SFT
STENTER
GROUND FLOOR PLAN
LAYOUT PLAN OF MPB G.F
ECHOTEX LTD.
Architectural
101



LAYOUT PLAN OF MPB 1st.Floor
1ST FLOOR PLAN
BATCH SECTION
8500 SFT
INSPECTION AREA
3400 SFT
OFFICE
1650 SFT
WALK WAY
KNITTING MACHINE (60 Nos.)
SEWING SAMPLE AREA
DENIM DRY PROCESS
BRUSHING SECTION
PP SPRAY SECTION
EXIT
d = 350 ft
D = 448 ft

Appendix-7: FDS Input.

```
&HEAD CHID='ECOTEX1'/
&TIME T_END=480.00/
&DUMP RENDER_FILE='Storage'/
&DUMP MASS_FILE=.TRUE.
&DUMP DT_DEVC
&MISC VISIBILITY_FACTOR=3.00/
&MESH ID='MESH',  IJK=400,80,25, XB=0.00,80.00,0.00,32.00,0.00,5.00 /
&MESH ID='MESH01', IJK=255,340,25, XB=0.00,51.00,32.00,100.00,0.00,5.00 /



/ See SFPE Handbook 3rd Edition Tables C.3 and 3-4.14 /
/ See NFPA Handbook, Table 6.17.2 /



&MATL ID='Polyester'
CONDUCTIVITY =0.2
SPECIFIC_HEAT =1.15
DENSITY=1345/

&REAC FUEL = 'Polyester'
SOOT_YIELD          = 0.091
CO_YIELD    = 0.070
C                   = 10
H                   =8
O                   =4
HEAT_OF_COMBUSTION=23800.0 /
```

```
&SURF ID='Polyester_fuel'
MATL_ID='Polyester'
THICKNESS=0.02
IGNITION_TEMPERATURE=349./
BURN_AWAY=.TRUE.
RGB=218,165,64

&SURF ID='BURNER', HRRPUA=2500., COLOR='RASPBERRY', RAMP_Q='fireramp' /
&RAMP ID='fireramp', T=0, F=0 /
&RAMP ID='fireramp', T=100, F=0.2 /
&RAMP ID='fireramp', T=200, F=1 /
&RAMP ID='fireramp', T=300, F=0.8 /
&RAMP ID='fireramp', T=400, F=0.2 /

&VENT XB= 12.0,15.0,2.0,5.0,0.2,0.2, SURF_ID='BURNER' /



&MATL ID='EXT WALL',
 SPECIFIC_HEAT=0.70,
 CONDUCTIVITY=0.038,
 DENSITY=24.00 / Glass Wool; SFPE Handbook 4th Edition Table B.7
&MATL ID='INT WALL',
 SPECIFIC_HEAT=0.84,
 CONDUCTIVITY=0.48,
 DENSITY=1440.00 / Plaster, Gypsum; SFPE Handbook 4th Edition Table B.7
&MATL ID='CONCRETE',
 SPECIFIC_HEAT=0.88,
 CONDUCTIVITY=1.37,
 DENSITY=2300.00 / SFPE Handbook 4th Edition Table B.7
&SPEC ID='SOOT', MASS_EXTINCTION_COEFFICIENT=8.7000000E003/
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&OBST XB=8.9,11.3, 1.5, 16, 0.0,1.5, SURF_IDS='Polyester_fuel' / rack 2
&OBST XB=8.9,11.3, 1.5, 16, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 2

&OBST XB=25,27.4, 1.5, 16, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 3
&OBST XB=25,27.4, 1.5, 16, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 3
&OBST XB=30.9,33.3, 1.5, 16, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 4
&OBST XB=30.9,33.3, 1.5, 16, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 4
&OBST XB=35.3,37.7, 1.5, 16, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 5
&OBST XB=35.3,37.7, 1.5, 16, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 5
&OBST XB=39.8,42.2, 1.5,16, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 6
&OBST XB=39.8,42.2, 1.5,16, 2.0,3.5, SURF_IDS='Polyester_fuel'/ rack 6

&OBST XB=44.8,47.2, 1.5,16, 0, 1.5, SURF_IDS='Polyester_fuel' / rack 7
&OBST XB=44.8,47.2, 1.5,16, 2.0, 3.5, SURF_IDS='Polyester_fuel' / rack 7
&OBST XB=50.6,53, 1.5, 16, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 8
&OBST XB=50.6,53, 1.5, 16, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 8
&OBST XB=55.6,58, 1.5, 16, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 9
&OBST XB=55.6,58, 1.5, 16, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 9
&OBST XB=61.4,63.8,1.5, 16,0,1.5, SURF_IDS='Polyester_fuel'/ rack 10
&OBST XB=61.4,63.8,1.5,16,2.0,3.5, SURF_IDS='Polyester_fuel'/ rack 10
&OBST XB=66,68.5,1.5,16,0,1.5, SURF_IDS='Polyester_fuel'/ rack 11
&OBST XB=66,68.5, 1.5, 16, 2.0,3.5, SURF_IDS='Polyester_fuel'/ rack 11

&OBST XB=3.0, 73.5, 19.2, 21.6, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 12
&OBST XB=3.0, 73.5, 19.2, 21.6, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 12
```

&OBST XB=3.0, 73.5, 24.9, 27.3, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 13
&OBST XB=3.0, 73.5, 24.9, 27.3, 2, 3.5, SURF_IDS='Polyester_fuel'/ rack 13

&OBST XB=3.0, 47.8, 30.9, 33.3, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 14
&OBST XB=3.0, 47.8, 30.9, 33.3, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 14

&OBST XB=3.0, 47.8, 35.5, 37.9, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 15
&OBST XB=3.0, 47.8, 35.5, 37.9, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 15
&OBST XB=3.0, 47.8, 42.3, 44.7, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 16
&OBST XB=3.0, 47.8, 42.3, 44.7, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 16

&OBST XB=3.0, 47.8, 46.5, 48.9, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 17
&OBST XB=3.0, 47.8, 46.5, 48.9, 2.0, 3.5, SURF_IDS='Polyester_fuel'/ rack 17

&OBST XB=3.0, 47.8, 53.2, 55.6, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 18
&OBST XB=3.0, 47.8, 53.2, 55.6, 2, 3.5, SURF_IDS='Polyester_fuel'/ rack 18

&OBST XB=3.0, 47.8, 58.7, 61.1, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 19
&OBST XB=3.0, 47.8, 58.7, 61.1, 2, 3.5, SURF_IDS='Polyester_fuel'/ rack 19

&OBST XB=3.0, 47.8, 64.4, 66.8, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 20
&OBST XB=3.0, 47.8, 64.4, 66.8, 2, 3.5, SURF_IDS='Polyester_fuel'/ rack 20

&OBST XB=3.0, 47.8, 70.5, 72.9, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 21
&OBST XB=3.0, 47.8, 70.5, 72.9, 2, 3.5, SURF_IDS='Polyester_fuel'/ rack 21

&OBST XB=3.0, 47.8, 76.3, 78.7, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 22
&OBST XB=3.0, 47.8, 76.3, 78.7, 2, 3.5, SURF_IDS='Polyester_fuel'/ rack 22

&OBST XB=3.0, 47.8, 81.6, 84, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 23
&OBST XB=3.0, 47.8, 81.6, 84, 2, 3.5, SURF_IDS='Polyester_fuel'/ rack 23

&OBST XB=3.0, 47.8, 87, 89.4, 0, 1.5, SURF_IDS='Polyester_fuel' / rack 24
&OBST XB=3.0, 47.8, 87, 89.4, 2, 3.5, SURF_IDS='Polyester_fuel' / rack 24

&OBST XB=3.0, 47.8, 92.5, 94.9, 0, 1.5, SURF_IDS='Polyester_fuel'/ rack 25
&OBST XB=3.0, 47.8, 92.5, 94.9, 2, 3.5, SURF_IDS='Polyester_fuel'/ rack 25

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&SURF ID='Ceiling', MATL_ID='CONCRETE', THICKNESS=0.20, COLOR='INVISIBLE' /
&SURF ID='Second Floor', MATL_ID='CONCRETE', THICKNESS=0.20, COLOR='INVISIBLE' /

&SURF ID='Main Floor', MATL_ID='CONCRETE', THICKNESS=0.20, COLOR='WHITE' /
&SURF ID='Interior Wall', MATL_ID='INT WALL', THICKNESS=0.20, COLOR='PINK' /

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&OBST XB=0.00,51.00,99.80,100.00,0.00,5.00, SURF_ID='Exterior Wall'/ back wall

&OBST XB=79.80,80.00,0.00,32.00,0.00,5.00, SURF_ID='Exterior Wall'/ right Wall-1
&OBST XB=51.00,80.00,31.80,32.00,0.00,5.00, SURF_ID='Exterior Wall'/ right Wall-2
&OBST XB=50.80,51.00,32.00,100.00,0.00,5.00, SURF_ID='Exterior Wall'/ right Wall-3

&OBST XB=0.00,80.00,0.00,32.00,4.80,5.00, SURF_ID='Ceiling'/ Ceiling, -1
Floor
&OBST XB=0.00,51.00,32.00,100.00,4.80,5.00, SURF_ID='Ceiling'/ Ceiling, -2

&OBST XB=0.00,80.00,00.00,32.0,0.00,0.2, SURF_ID='Main Floor'/ floor-1
&OBST XB=0.00,51.00,32.00,100.0,0.00,0.2, SURF_ID='Main Floor'/ floor-2

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&VENT ID='window2', SURF_ID='OPEN', XB=41.00,43.00,0.0,0.0,1.0,4.00 / Hole-2-f

&VENT ID='window3', SURF_ID='OPEN',XB=45.00,47.00,00.0,00.0,1.00,4.00/  Hole-3-f



&VENT ID='window4', SURF_ID='OPEN', XB=49.00,51.00,0.0,0.0,1.0,4.00 / Hole-4-f

&VENT ID='window5', SURF_ID='OPEN', XB=53.00,55.00,0.0,0.0,1.0,4.00 / Hole-5-f

&VENT ID='window6', SURF_ID='OPEN',XB=57.00,59.00,00.0,00.0,1.0,4.00/  Hole-6-f


&VENT ID='window7', SURF_ID='OPEN', XB=61.00,63.00,0.0,0.0,1.0,4.00 / Hole-7-f

&VENT ID='window8', SURF_ID='OPEN', XB=65.00,67.00,0.0,0.0,1.0,4.00 / Hole-8-f

&VENT ID='window9', SURF_ID='OPEN',XB=69.00,71.00,00.0,00.0,1.0,4.00/  Hole-9-f


&VENT ID='window10', SURF_ID='OPEN',XB=00.00,00.00,13.0,15.0,1.0,4.00/  Hole-10-L
&VENT ID='window11', SURF_ID='OPEN',XB=00.00,00.00,19.0,22.0,1.0,4.00/  Hole-11-L
&VENT ID='window12', SURF_ID='OPEN',XB=00.00,00.00,26.0,29.0,1.0,4.00/  Hole-12-L
&VENT ID='window13', SURF_ID='OPEN',XB=00.00,00.00,33.0,36.0,1.0,4.00/  Hole-13-L
&VENT ID='window14', SURF_ID='OPEN',XB=00.00,00.00,40.0,43.0,1.0,4.00/  Hole-14-L
&VENT ID='window15', SURF_ID='OPEN',XB=00.00,00.00,47.0,50.0,1.0,4.00/  Hole-15-L
```

&VENT ID='window16', SURF_ID='OPEN',XB=00.00,00.00,54.0,57.0,1.0,4.00/ Hole-16-L
&VENT ID='window17', SURF_ID='OPEN',XB=00.00,00.00,61.0,64.0,1.0,4.00/ Hole-17-L
&VENT ID='window18', SURF_ID='OPEN',XB=00.00,00.00,68.0,71.0,1.0,4.00/ Hole-18-L
&VENT ID='window19', SURF_ID='OPEN',XB=00.00,00.00,75.0,78.0,1.0,4.00/ Hole-19-L

&VENT ID='window20', SURF_ID='OPEN',XB=8.00,10.00,100.0,100.0,1.0,4.00/ Hole-20-b
&VENT ID='window21', SURF_ID='OPEN',XB=18.00,20.00,100.0,100.0,1.0,4.00/ Hole-21-b
&VENT ID='window22', SURF_ID='OPEN',XB=28.00,30.00,100.0,100.0,1.0,4.00/ Hole-22-b
&VENT ID='window23', SURF_ID='OPEN',XB=38.00,40.00,100.0,100.0,1.0,4.00/ Hole-23-b
&VENT ID='window24', SURF_ID='OPEN',XB=48.00,50.00,100.0,100.0,1.0,4.00/ Hole-24-b

&VENT ID='window25', SURF_ID='OPEN',XB=51.00,51.00,37.0,40.0,1.0,4.00/ Hole-25-r
&VENT ID='window26', SURF_ID='OPEN',XB=51.00,51.00,47.0,50.0,1.0,4.00/ Hole-26-r
&VENT ID='window27', SURF_ID='OPEN',XB=51.00,51.00,57.0,60.0,1.0,4.00/ Hole-27-r
&VENT ID='window28', SURF_ID='OPEN',XB=51.00,51.00,67.0,70.0,1.0,4.00/ Hole-28-r
&VENT ID='window29', SURF_ID='OPEN',XB=51.00,51.00,77.0,80.0,1.0,4.00/ Hole-29-r
&VENT ID='window30', SURF_ID='OPEN',XB=51.00,51.00,87.0,90.0,1.0,4.00/ Hole-30-r

&VENT ID='window31', SURF_ID='OPEN',XB=55.00,57.00,32.0,32.0,1.0,4.00/ Hole-31-r
&VENT ID='window32', SURF_ID='OPEN',XB=65.00,67.00,32.0,32.0,1.0,4.00/ Hole-32-r
&VENT ID='window33', SURF_ID='OPEN',XB=75.00,77.00,32.0,32.0,1.0,4.00/ Hole-33-r

&SPEC ID='WATER VAPOR'/
&PART ID='water drops', SPEC_ID='WATER VAPOR', AGE=4.00, DIAMETER=1000,COLOR='BLUE' /
&PROP ID='SPK', QUANTITY='SPRINKLER LINK TEMPERATURE', RTI=80., C_FACTOR=0.7,ACTIVATION_TEMPERATURE=68., OFFSET=0.10, PART_ID='water drops', FLOW_RATE=189.3,
PARTICLE_VELOCITY=10., SPRAY_ANGLE=30.,80.,SMOKEVIEW_ID='sprinkler_upright'

/

```
&DEVC ID='SPR_1_1', XYZ=1,2,4.7, PROP_ID='SPK' /L-1
&DEVC ID='SPR_1_2', XYZ=4,2,4.7, PROP_ID='SPK' /L-1
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&SLCF QUANTITY='TEMPERATURE',PBY=95.0 /


&SLCF QUANTITY='TEMPERATURE',PBZ=4.20 /
&SLCF QUANTITY='TEMPERATURE',PBZ=1.82 /
&SLCF QUANTITY='TEMPERATURE',PBZ=1.20 /
194
&SLCF QUANTITY='VISIBILITY',PBX=15.0 /
&SLCF QUANTITY='VISIBILITY',PBX=30.0 /
&SLCF QUANTITY='VISIBILITY',PBX=45.0 /
&SLCF QUANTITY='VISIBILITY',PBX=60.0 /
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&SLCF QUANTITY='VISIBILITY',PBX=75.0 /

&SLCF QUANTITY='VISIBILITY',PBY=15.0 /
&SLCF QUANTITY='VISIBILITY',PBY=30.0 /
&SLCF QUANTITY='VISIBILITY',PBY=45.0 /
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&SLCF QUANTITY='VISIBILITY',PBY=75.0 /
&SLCF QUANTITY='VISIBILITY',PBY=90.0 /


&SLCF QUANTITY='VISIBILITY',PBZ=4.20 /
&SLCF QUANTITY='VISIBILITY',PBZ=1.82 /
&SLCF QUANTITY='VISIBILITY',PBZ=1.20 /

&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBX=15.0 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBX=30.0 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBX=45.0 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBX=60.0 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBX=75.0 /


&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBY=15.0 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBY=30.0 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBY=45.0 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBY=60.0 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBY=75.0 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBY=90.0 /

&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBZ=4.20 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBZ=2.02 /
&SLCF QUANTITY='MASS FRACTION',SPEC_ID='CARBON MONOXIDE',PBZ=1.20 /
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&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBX=15.0 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBX=30.0 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBX=45.0 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBX=60.0 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBX=75.0 /

&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBY=15.0 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBY=30.0 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBY=45.0 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBY=60.0 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBY=75.0 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBY=90.0 /

&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBZ=4.20 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBZ=1.82 /
&SLCF QUANTITY='DENSITY', SPEC_ID='SOOT', PBZ=1.20 /
&SLCF QUANTITY='carbon monoxide', PBZ=1.82/ 6' above Level 1 (RESULTS IN PPM)
&BNDF QUANTITY='GAUGE HEAT FLUX'

&TRAIL/
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Appendix-8: Hydraulic Calculations:

Hydraulic calculation at remote Area#1

STEP NO.	NOZZLE IDENT. AND LOCATION	FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NORMAL PRESSURE	NOTES	STEP NO.	NOZZLE IDENT. AND LOCATION	FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NOTES		
					L=12		Pt=7	Pt=7	Q						L=60		Pt=23.163			
		q=29.63	1.5						29.63241468			q=43.8						Qadj=		
	1				F	0.033	Pe	Pv					4		F	0.08	Pe	43.809504		
		Q=29.63			T=12		Pf=0.4	Pn				Q=531.048			T=60		Pf=4.6			
					L=12		Pt=7.4	Pt							L=117		Pt=27.763			
		q=30.47				0.124			30.46729394		90 ELL	q		1ELL90=14						531.048
	2		1.5		F		Pe	Pv					6		F=54	0.01	Pe			
														1 CV+BV						
		Q=60.1			T=12		Pf=1.48	Pn				Q=531.048		32+10=40	T=171		Pf=1.87			
					L=12		Pt=8.88	Pt		TOR					L=697		Pt=29.63			
		q=33.38				0.28					hose	q=250								
	3		1.5		F		Pe	Pv	33.37524831		steam		6	3EL90	F=42		Pe=50.66	50.661	65	
														42		0.02				
		Q=93.48			T=12		Pf=3.36	Pn				Q=781			T=739		Pf=16.46		96.75	29.633
					L=30		Pt=12.24	Pt		BOR					L20		Pt=96.75			
		q=68.544										q		1EL90+1CV		0.006		10 ft elevation		
	4		2		F	0.23	Pe	Pv	68.544				8	1GV	F=67		Pe=4.33	4.33		162.024
		Q=162.024			T=30		Pf=6.88	Pn				Q=781		18+4+45	T=87		Pf=0.5			89.2
					L=1		Pt=19.12	Pt							L		Pt=101.58			
		q	2									q								101.58
					F=10	0.02	Pe=0.433	Pv							F		Pe			
		Q=162.024			T=11		Pf=2.52	Pn				Q			T		Pf			
					L=10		Pt=22.073	Pt							L		Pt			
		q							K=			q								23.163
			4		F		Pe	Pv	34.41637114						F		Pe			
						0.009														
		Q=162.024			T=10		Pf=0.09	Pn				Q			T		Pf			
					L=10		Pt=22.163	Pt							L		Pt			
	Spk5-8	q=162.024										q								
			4		F	0.03	Pe	Pv	162.024						F		Pe			
		Q=324.048			T=10		Pf=0.32	Pn				Q			T		Pf			
					L=10		Pt=22.483	Pt							L		Pt			487.248
	SpK-9-12	q=163.2										q								
			4		F	0.068	Pe	Pv	163.1894981						F		Pe			
		Q=487.248			T=10		Pf=0.68	Pn				Q			T		Pf			
					L		Pt=23.163	Pt							L		Pt			389.19
		q										q								
					F		Pe	Pv							F		Pe			
		Q			T		Pf	Pn				Q			T		Pf			
					L=30		Pt=7	Pt							L		Pt			
	SpK-13	q	2			0.009			Q=29.63			q								
					F		Pe	Pv							F		Pe			
		Q=39.63			T=30		Pf=0.3	Pn				Q			T		Pf			
				1T	L=1		Pt=7.3	Pt							L		Pt			
		q										q								
			2		F=10	0.009	Pe=0.433	Pv							F		Pe			
		Q=29.63			T=11		Pf=0.1	Pn				Q			T		Pf			
							Pt=7.833										Pt			
																				7.833

Hydraulic calculation at remote Area#2.

STEP NO.	NOZZLE IDENT. AND LOCATION	FLOW IN G.P.M.	PIPE SIZE	FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NORMAL PRESSURE	NOTES	STEP NO.	NOZZLE IDENT. AND LOCATION	FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NOTES		
					L=12		Pt=7	Pt=7	Q						L=15		Pt=23.163			
		q=29.63	1.5						29.6324147			q=43.8	4.03					Qadj=		
	1				F	0.033	Pc	Pv					4	2T	F=30	0.08	Pc	43.8095		29.47
		Q=29.63			T=12		Pf=0.4	Pn				Q=531.048			T=45		Pf=3.61			
					L=12		Pt=7.4	Pt							L=194		Pt=26.77			
		q=30.47				0.124			30.4672939		90 ELL	q		1ELL90=14						531.048
	2		1.5		F		Pc	Pv					6		F=54	0.01	Pc			
														1 CV+BV						248
		Q=60.1			T=12		Pf=1.48	Pn				Q=531.048		32+10=40	T=248		Pf=2.7			
					L=12		Pt=8.88	Pt		TOR					L=170		Pt=29.47			
		q=33.38				0.28					hose	q=		1GV						
	3		1.5		F		Pc	Pv	33.3752483		steam		6	3EL90	F=43		Pc=50.66	50.661	65	
														42		0.02				
		Q=93.48			T=12		Pf=3.36	Pn				Q=531			T=113		Pf=1.2		96.75	[illegible]
					L=30		Pt=12.24	Pt		BOR					L20		Pt=81.33		81.33	
		q=68.544										q=250		1EL90+1CV		0.006		10 ft elevation		
	4		2		F	0.23	Pc	Pv	68.544				8	1GV	F=67		Pc=4.33	4.33		162.024
		Q=162.024			T=30		Pf=6.88	Pn				Q=781		18+4+45	T=87		Pf=0.249		85.909	85.2
					L=1		Pt=19.12	Pt							L		Pt=86			
		q	2									q								[illegible]
					F=10	0.02	Pc=0.433	Pv							F		Pc			
		Q=162.024			T=11		Pf=2.52	Pn				Q			T		Pf			
					L=10		Pt=22.073	Pt							L		Pt			
		q							K=			q								29.163
			4		F		Pc	Pv	34.4163711						F		Pc			
						0.009														
		Q=162.024			T=10		Pf=0.09	Pn				Q			T		Pf			
					L=10		Pt=22.163	Pt							L		Pt			
	Spk5-8	q=162.024										q								
			4		F	0.03	Pc	Pv	162.024						F		Pc			
		Q=324.048			T=10		Pf=0.32	Pn				Q			T		Pf			
					L=10		Pt=22.483	Pt							L		Pt			487.248
	SpK-9-12	q=163.2										q								
			4		F	0.068	Pc	Pv	163.189498						F		Pc			
		Q=487.248			T=10		Pf=0.68	Pn				Q			T		Pf			
					L		Pt=23.163	Pt							L		Pt			[illegible]
		q										q								
					F		Pc	Pv							F		Pc			
		Q			T		Pf	Pn				Q			T		Pf			
					L=30		Pt=7	Pt							L		Pt			
	SpK-13	q	2			0.009			Q=29.63			q								
					F		Pc	Pv							F		Pc			
		Q=29.63			T=30		Pf=0.3	Pn				Q			T		Pf			
				1T	L=1		Pt=7.3	Pt							L		Pt			
		q										q								
			2		F=10	0.009	Pc=0.433	Pv							F		Pc			
		Q=29.63			T=11		Pf=0.1	Pn				Q			T		Pf			
							Pt=7.833										Pt			
																				7.833

Hydraulic calculation at remote Area#3.

Row	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	STEP NO.	NOZZLE IDENT. AND LOCATION		FLOW IN G.P.M.	PIPE SIZE	FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NORMAL PRESSURE	NOTES	STEP NO.	NOZZLE IDENT. AND LOCATION		FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NOTES			
3							L=12		Pt=7	Pt=7	Q							L=60		Pt=23.163				
4				q=29.63	1.5						29.63241468				q=43.8						Qadj=			
5			1				F	0.033	Pe	Pv						4		F	0.08	Pe	43.809504			
7				Q=29.63			T=12		Pf=0.4	Pn					Q=531.048			T=60		Pf=4.6				
9							L=12		Pt=7.4	Pt								L=117		Pt=27.763				
10				q=30.47				0.124			30.46729394			90 ELL	q								531.048	
11			2		1.5		F		Pe	Pv						6		F=56	0.01	Pe				
12																	1 CV+BV+1EL							
13				Q=60.1			T=12		Pf=1.48	Pn					Q=531		32+10+14=56	T=173		Pf=1.88				
15							L=12		Pt=8.88	Pt		TOR						L=170		Pt=29.64		29.643		
16				q=33.38				0.28						hose	q=		1GV=3							
17			3		1.5		F		Pe	Pv	33.37524831			steam		6	3EL90	F=45		Pe=50.66	50.661	65		
18																	42		0.01					
19				Q=93.48			T=12		Pf=3.36	Pn					Q=531			T=215		Pf=2.34		96.75	29.633	
21							L=30		Pt=12.24	Pt		BOR						L20		Pt=82.64		82.64		
22				q=68.544											q=250		1EL90+1CV		0.006		10 ft elevation			
23			4		2		F	0.23	Pe	Pv	68.544					8	1GV	F=67		Pe=4.33	4.33		162.024	
25				Q=162.024			T=30		Pf=6.88	Pn					Q=781	7.98	18+4+45	T=87		Pf=0.5			89.2	
27							L=1		Pt=19.12	Pt								L		Pt=88		87.47		
28				q	2										q								101.58	
29							F=10	0.02	Pe=0.433	Pv								F		Pe				
31				Q=162.024			T=11		Pf=2.52	Pn					Q			T		Pf				
33							L=10		Pt=22.073	Pt								L		Pt				
34				q							K=				q								23.163	
35					4		F		Pe	Pv	34.41637114							F		Pe				
36								0.009																
37				Q=162.024			T=10		Pf=0.09	Pn					Q			T		Pf				
39							L=10		Pt=22.163	Pt								L		Pt				
40			Spk5-8	q=162.024											q									
41					4		F	0.03	Pe	Pv	162.024							F		Pe				
43				Q=324.048			T=10		Pf=0.32	Pn					Q			T		Pf				
45							L=10		Pt=22.483	Pt								L		Pt			487.248	
46			SpK-9-12	q=163.2											q									
47					4		F	0.068	Pe	Pv	163.1894981							F		Pe				
49				Q=487.248			T=10		Pf=0.68	Pn					Q			T		Pf				
51							L		Pt=23.163	Pt								L		Pt			389.19	
52				q											q									
53							F		Pe	Pv								F		Pe				
55				Q			T		Pf	Pn					Q			T		Pf				
57							L=30		Pt=7	Pt								L		Pt				
58			SpK-13	q	2			0.009			Q=29.63				q									
59							F		Pe	Pv								F		Pe				
61				Q=39.63			T=30		Pf=0.3	Pn					Q			T		Pf				
63						1T	L=1		Pt=7.3	Pt								L		Pt				
64				q											q									
65					2		F=10	0.009	Pe=0.433	Pv								F		Pe				
67				Q=29.63			T=11		Pf=0.1	Pn					Q			T		Pf				
69									Pt=7.833											Pt				
70																							7.833	

Hydraulic calculation at remote Area#4.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
STEP NO.	NOZZLE IDENT. AND LOCATION		FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NORMAL PRESSURE	NOTES	STEP NO.	NOZZLE IDENT. AND LOCATION		FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NOTES	
							C-120			K-5.6											
1						L-12 ft		Pt-18.36	Pt								L-60		Pt-30.098		
			q					Po-		Q-120*0.2				q-							622
		Spk-1		1		F			Pv	24					4		F	0.037	Po		
				1.049			0.182								4.026						54.736
			Q-24			T-12		Pf-2.18	Pn	18.3673469				Q-350.76			T-60		Pf-2.235		
						L-12		Pt-20.54	Pt	28.0055994							L-117		Pt-32.33		
		SpK-2	q-25.37	1.38			0.182						90 ELL	q		1ELL90-14					29.658
2						F-		Po	Pv						6		F-54	0.005	Po		
															6.065	1CV+BV					
			Q-49.37			T-12		Pf-2.18	Pn					Q-350.76		32+10-40	T-171		Pf-0.86		
				1.5		L-12		Pt-22.72	Pt		TOR						L-622		Pt-33.19	42 ft elevation	
3			q-26.69											q-							
		SpK-3		1.61		F	0.19	Po	Pv						6	3EL90	F-42		Po-18.186	18.186	65
																42		0.005			
			Q-76.06			T-12		Pf-2.29	Pn					Q-350.76			T-664		Pf-3.36		96.75
						L-31		Pt-25.01	Pt		BOR						L20		Pt-54.736		
4		SpK-4	q-28	2	1tee		0.1			1X0.433				q		1EL90+1CV		0.001		10 ft elevation	
				2.067		F-10		Po-0.433	Pv						8	1GV	F-67		Po-4.33	4.33	44.558
																					4.33
			Q-104.06			T-41		Pf-4.1	Pn					Q-350.76		18+4+45	T-87		Pf-0.11		0.92
						L-10		29.54													49.808
									Pt	Km							L		Pt-59.176 PSI		
5			q-	4	1Tee	F-20				19.1423432			Hose	q-250							59.176
				4.026			0.0039	Po	Pv								F		Po		
			Q-104.06			T-30		Pf-0.118	Pn					Q- 600.76			T		Pf		
						L-10		Pt-29.658													
									Pt								L		Pt		
6			q-104.34							104.589735				q							
	BL-2	SpK-5-8		4.026		F	0.014	Po	Pv								F		Po		
																					19.133
			Q-208.40			T-10		Pf-0.14	Pn					Q			T		Pf		
						L-10		Pt-29.798	Pt								L		Pt		
			q-104.59	4										q							
7	BL-3	Spk-9-12				F	0.03	Po	Pv								F		Po		
				4.026																	
			Q- 313			T-10		Pf-0.3	Pn					Q			T		Pf		
						L		Pt-30.098	Pt								L		Pt		
			q											q							
						F		Po	Pv								F		Po		
			Q			T		Pf	Pn					Q			T		Pf		
						L-31		Pt-18.36	Pt								L		Pt		350.76
		Spk-13	q-24	2.067	2T		0.006							q							
						F-20		Po-0.433	Pv								F		Po		
			Q			T-51		Pf-0.34	Pn					Q			T		Pf		
						L		Pt-19.13	Pt								L		Pt		
			q											q							
						F		Po	Pv	Qadj							F		Po		
										37.7601673											
			Q			T		Pf	Pn					Q			T		Pf		
						L		Pt-30.098	Pt								L		Pt		
			q-37.76											q							
						F		Po	Pv								F		Po		
			Q-350.76			T		Pf	Pn					Q			T		Pf		
								Pt-30.098											Pt		

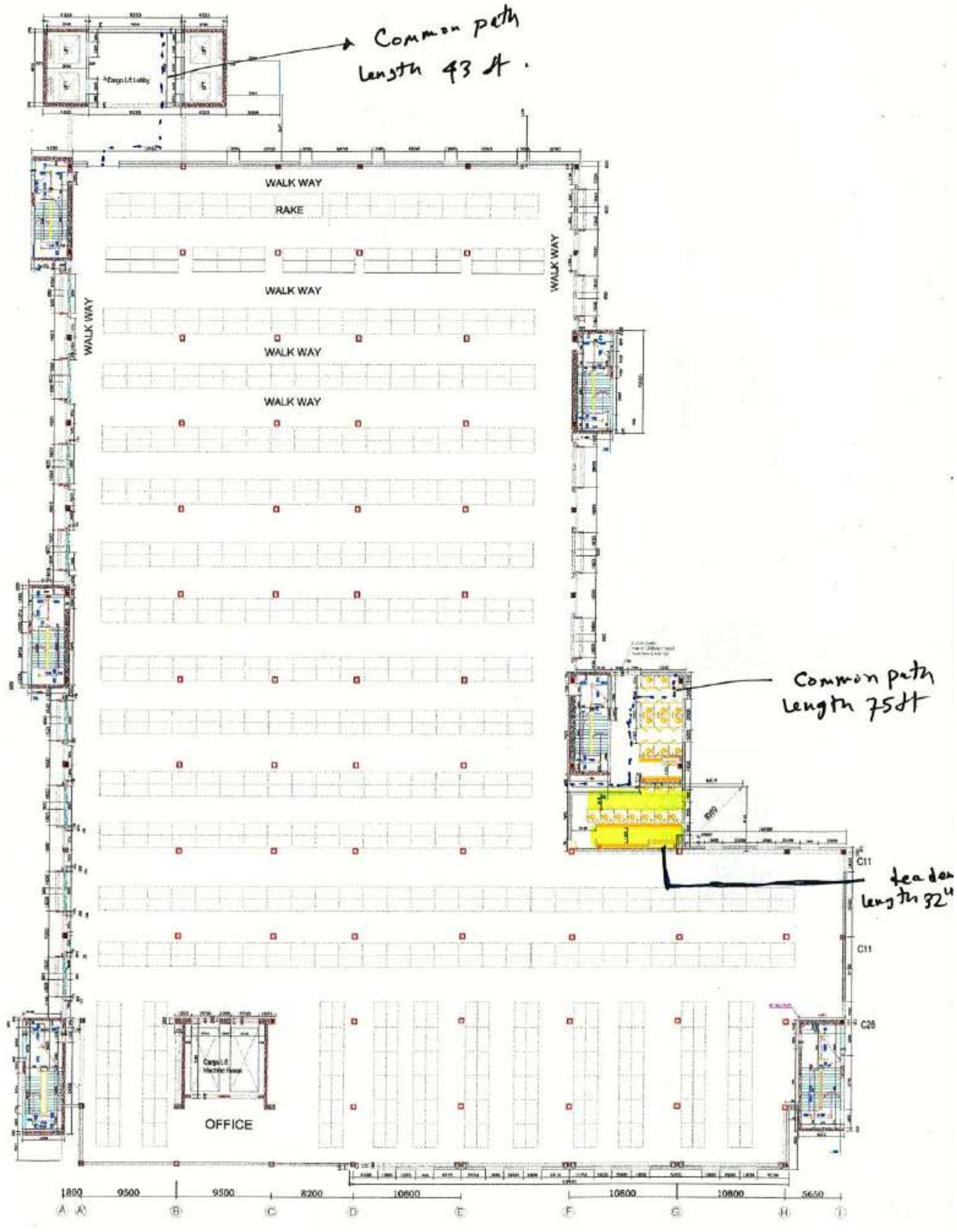
Hydraulic calculation at remote Area#5.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
STEP NO.	NOZZLE IDENT. AND LOCATION		FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NORMAL PRESSURE	NOTES	STEP NO.		NOZZLE IDENT. AND LOCATION	FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NOTES	
							C-120			K-8											
1						L -12 ft		Pt-9	Pt								L-60		Pt-21.74		
			q					Po-		Q-120*0.2				q-							
		Spk-1		1		F			Pv	24					4		F	0.04	Po		
				1.049			0.182								4.04						
			Q-24			T-12		Pf-2.18	Pn					Q-373			T-60		Pf-2.5		
						L-12		Pt-11.18	Pt								L-117		Pt-24.24		
		SpK-2	q-26.75	1.38			0.19						90 ELL	q		1ELL90-14					
2						F -		Po	Pv						6		F-54	0.005	Po		
															6.07	1CV+BV					
			Q-50.74			T- 12		Pf-2.29	Pn					Q-373		32+10-40	T-171		Pf-0.97		
				1.5		L-12		Pt-13.47	Pt		TOR						L-606		Pt-29.63		
3			q-29.36											q-							
		SpK-3		1.61		F	0.21	Po	Pv						6	3EL90	F-42		Po-11.258	11.258	65
																42		0.005			
			Q-80.1			T-12		Pf-2.5	Pn					Q-373			T-648		Pf-3.67		96.75
						L-31		Pt-15.97	Pt		BOR						L20		Pt-44.558		
4		SpK-4	q-31.96	2	1tee		0.11			1X0.433				q		1EL90+1CV		0.001		10 ft elevation	
				2.067		F-10		Po-0.433	Pv						8	1GV	F-67		Po-4.33	4.33	44.558
																					4.33
			Q-112.06			T-41		Pf-4.7	Pn					Q-373		18+4+45	T-87		Pf-0.92		0.92
						L-10		21.103													49.808
									Pt								L		Pt-50 PSI		
5			q-	4	1Tee	F-20							Hose	q-250							
				4.026			0.0045	Po	Pv								F		Po		
			Q-112.06			T-30		Pf-0.14	Pn					Q-623			T		Pf		
						L-10		Pt-21.24													
									Pt								L		Pt		
6			q-112.42											q							
	BL-2	SpK-5-8		4.026		F	0.016	Po	Pv								F		Po		
			Q-224.48			T-10		Pf-0.16	Pn					Q			T		Pf		
						L-10		Pt-21.4	Pt								L		Pt		
			q-112.84	4										q							
7	BL-3	Spk-9-12				F	0.034	Po	Pv								F		Po		
				4.026																	
			Q-337.32			T-10		Pf-0.34	Pn					Q			T		Pf		
						L		Pt-21.74	Pt								L		Pt		
			q											q							
						F		Po	Pv								F		Po		
			Q			T		Pf	Pn					Q			T		Pf		
						L-31		Pt-9	Pt								L		Pt		
		Spk-13	q-24	2.067	2T		0.006							q							
						F-20		Po-0.433	Pv								F		Po		
			Q			T-51		Pf-0.34	Pn					Q			T		Pf		
						L		Pt-9.77	Pt								L		Pt		
			q											q							
						F		Po	Pv								F		Po		
			Q			T		Pf	Pn					Q			T		Pf		
						L		Pt-21.74	Pt								L		Pt		
			q-35.8											q							
						F		Po	Pv								F		Po		
			Q-373			T		Pf	Pn					Q			T		Pf		
								Pt-21.74											Pt		

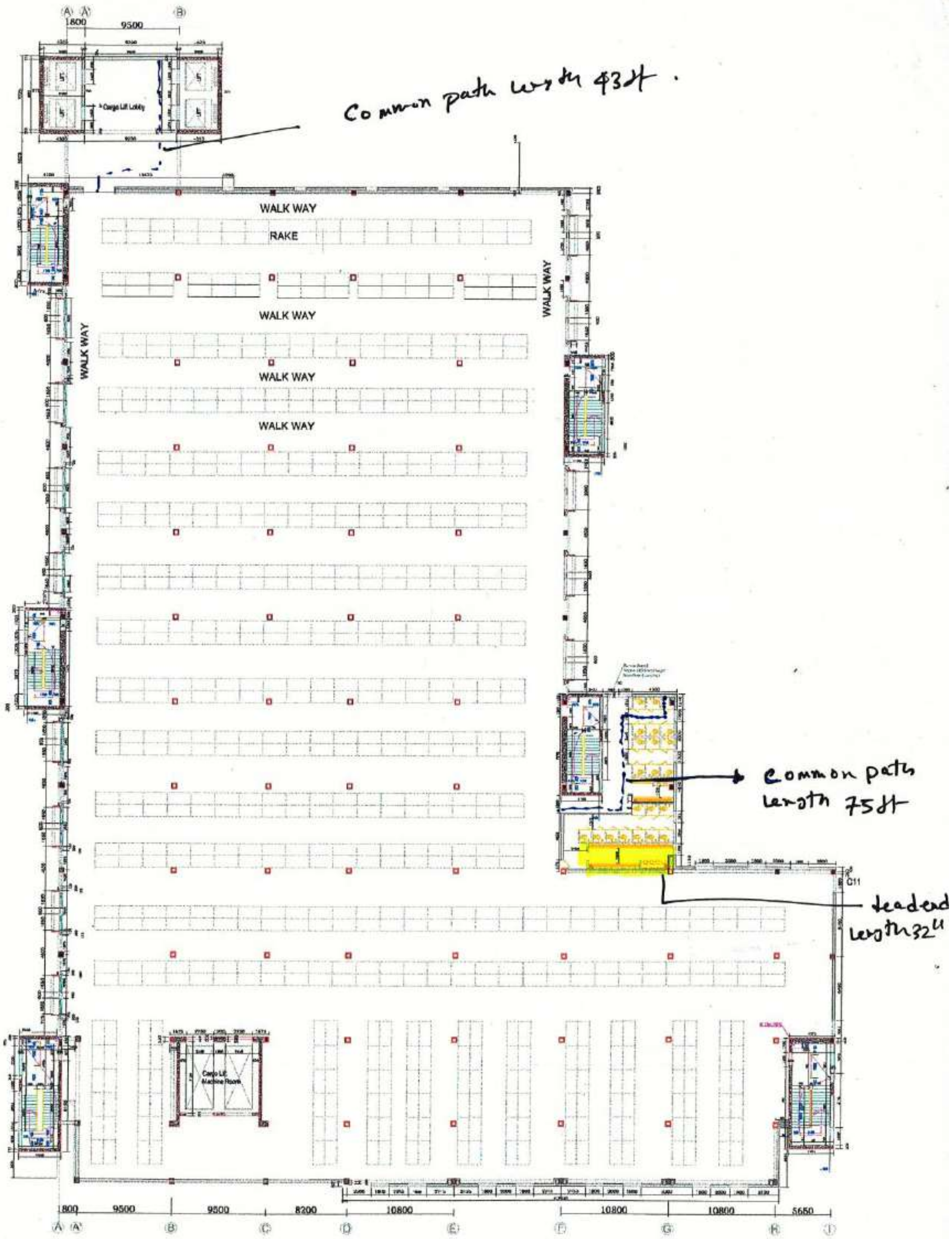
Standpipe Hydraulic calculation:

STEP NO.	NOZZLE IDENT. AND LOCATION	FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NORMAL PRESSURE	NOTES	STEP NO.	NOZZLE IDENT. AND LOCATION	FLOW IN G.P.M.	PIPE SIZE	PIPE FITTINGS AND DEVICES	EQUIV PIPE LENGTH	FRICTION LOSS P.S.I./FOOT	PRESSURE SUMMARY	NOTES
				90n deg Angle	L=1	C factor =120	Pt=100	Pt							L		Pt=100	
	127	q=250	2-1/2inch	Valve (31)								q						
			1/2/1900	Tee(12)	F=43	0.215	Pc	Pv							F		Pc	
		Q=250			T=44		Pf=9.47	Pn				Q			T		Pf	
					L=14		Pt=109.47	Pt							L		Pt	
	113	q=										q						
			6.065		F	0.002	Pc=6.96	Pv	6.062						F		Pc	
		Q=250			T=14		Pf=0.03	Pn				Q			T		Pf	
					L=113		Pt= 115.5	Pt							L		Pt	
	113	q=250							115.562			q						
			6.065		F	0.009	Pc=48.9	Pv	48.929						F		Pc	
		Q=500			T=113		Pf=1.1	Pn	165.8			Q			T		Pf	
					L=140		Pt= 165	Pt							L		Pt	
		q										q						
			6.065	1Tee=20	F=20	0.009	Pc	Pv							F		Pc	
		Q=500			T=160		Pf=1.3	Pn	166.3			Q			T		Pf	
					L=186		Pt=166.3	Pt							L		Pt	
		q=250		1Tee=35		0.05						q						
			7.981		F=35		Pc	Pv							F		Pc	186
		Q=750			T=221		Pf=1.19	Pn	167.49			Q			T		Pf	
					L=450		Pt=167.4	Pt	221						L		Pt	
		q=250		1Tee,2EL								q						
			7.981		F=71	0.009	Pc	Pv							F		Pc	
		Q=1000			T=521		Pf=4.8	Pn				Q			T		Pf	
					L=521		Pt= 172	Pt	172.2						L		Pt	
		q										q						
					F=		Pc	Pv							F		Pc	
		Q			T=		Pf	Pn				Q			T		Pf	
					L		Pt	Pt							L		Pt	
		q										q						
					F		Pc	Pv							F		Pc	
		Q			T		Pf	Pn				Q			T		Pf	
					L		Pt	Pt							L		Pt	
		q										q						
					F		Pc	Pv							F		Pc	
		Q			T		Pf	Pn				Q			T		Pf	
					L		Pt	Pt							L		Pt	
		q										q						
					F		Pc	Pv							F		Pc	
		Q			T		Pf	Pn				Q			T		Pf	
					L		Pt	Pt							L		Pt	
		q										q						
					F		Pc	Pv							F		Pc	
		Q			T		Pf	Pn				Q			T		Pf	

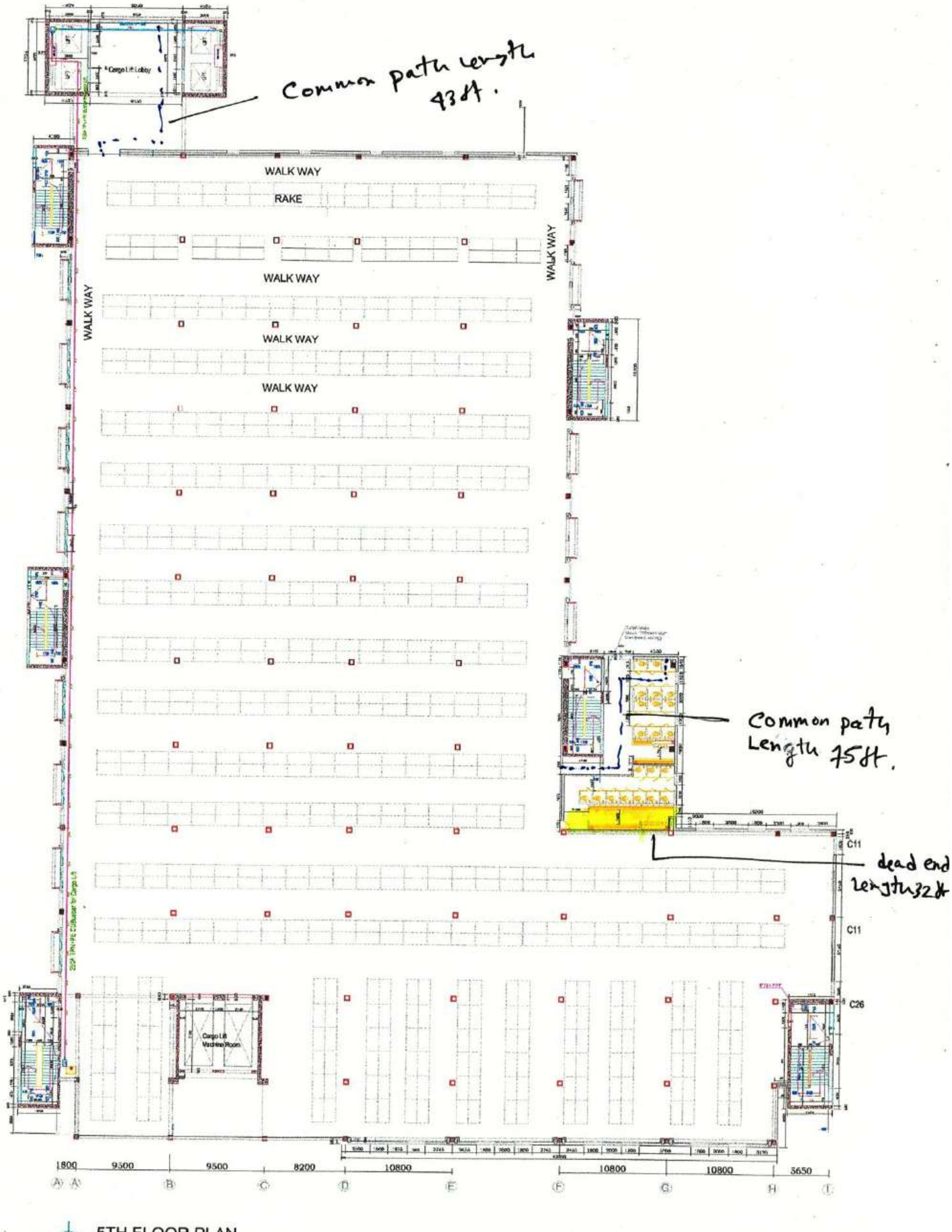
Appendix-9: Common Path and dead-end



4TH FLOOR PLAN
YARN STORE (capacity=2500 ton)

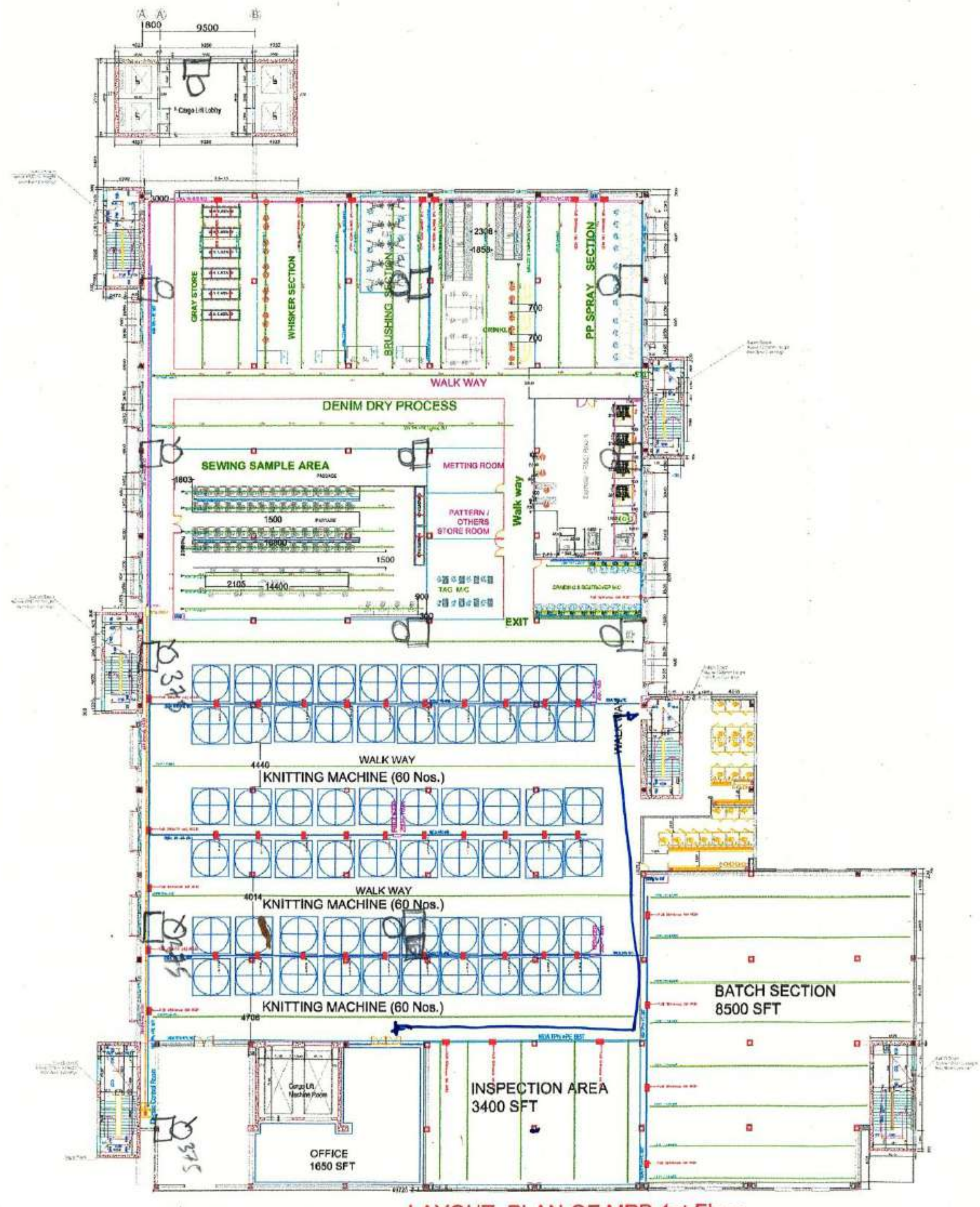


3RD FLOOR PLAN
GREY FABRIC STORE (capacity=2500 ton)



5TH FLOOR PLAN

FINISHED FABRIC /HANGER/CARTON STORE (capacity=2500 ton)

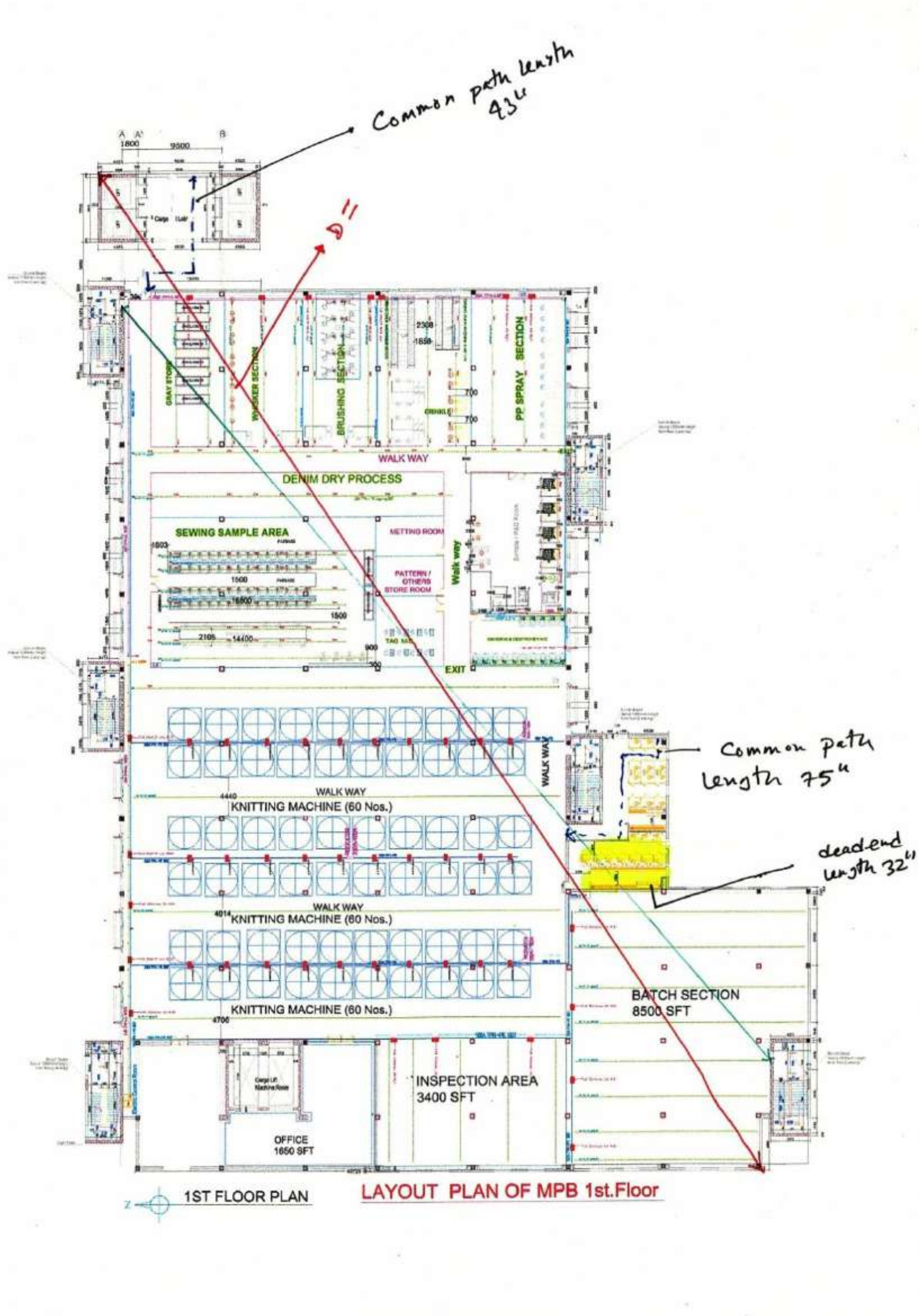


1ST FLOOR PLAN

LAYOUT PLAN OF MPB 1st.Floor

1650/100 = 16.5 = 17 persons

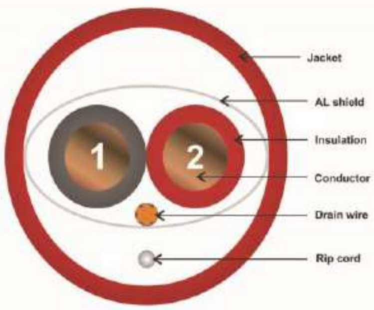
D = 170 ft


Common path length 43"
D"
GRAY STORE
WHISKER SECTION
BRUSHING SECTION
PP SPRAY SECTION
CRINKLE
WALK WAY
DENIM DRY PROCESS
SEWING SAMPLE AREA
METTING ROOM
PATTERN / OTHERS STORE ROOM
Walk way
EXIT
Common path length 75"
dead end length 32"
WALK WAY
KNITTING MACHINE (60 Nos.)
WALK WAY
KNITTING MACHINE (60 Nos.)
KNITTING MACHINE (60 Nos.)
BATCH SECTION
8500 SFT
INSPECTION AREA
3400 SFT
OFFICE
1650 SFT
1ST FLOOR PLAN
LAYOUT PLAN OF MPB 1st.Floor

Appendix-9: Fire Alarm catalog.

TPMCSTEEL
Your reliable firefighting supplier

AWG UL fire alarm cable (Shielded)



• Certificate:	UL Listed
• Brand:	TPMC E489608
• Conductor:	Bare copper
• Insulation (dielectric):	Black or red PVC
• Insulation thickness:	22 ~ 16AWG: 0.010 inch (0.25 mm) 14 ~ 12AWG: 0.013 inch (0.33mm)
• Jacket:	Red PVC
• Jacket thickness:	THK: 0.017 inch (0.43 mm)
• Shield:	Aluminum mylar
• Drain wire (earth wire):	Tinned copper
• Drain wire size:	7-strand x 0.2mm, with 0.22m^2
• Rip cord:	150D Nylon

Available size

Conductor size	Core	Cross-section area	DC Resistance at 20°C	Nominal OD of cable	Ref. No.
inch / mm	Solid / 7-strand	mm^2	Max, Ω/km	inch / mm	
22AWG x 4C (0.0253/0.64)	Solid	0.32	59.1	0.182 / 4.62	C02-AWG22-4
22AWG x 4C (0.0295/0.75)	7-strand	0.44	55.4	0.213 / 5.42	C02-AWG22-4S
18AWG x 2C (0.0403/1.02)	Solid	0.82	21.4	0.187 / 4.75	C02-AWG18-2
18AWG x 4C (0.0403/1.02)	Solid	0.82	21.4	0.216 / 5.49	C02-AWG18-4
18AWG x 2C (0.0403/1.17)	7-strand	1.07	21.9	0.214 / 5.45	C02-AWG18-2S
18AWG x 4C (0.0403/1.17)	7-strand	1.07	21.9	0.248 / 6.29	C02-AWG18-4S
16AWG x 2C (0.0508/1.29)	Solid	1.31	13.5	0.206 / 5.23	C02-AWG16-2
16AWG x 4C (0.0508/1.29)	Solid	1.31	13.5	0.240 / 6.10	C02-AWG16-4
16AWG x 2C (0.0508/1.50)	7-strand	1.77	13.7	0.240 / 6.09	C02-AWG16-2S
16AWG x 4C (0.0508/1.50)	7-strand	1.77	13.7	0.279 / 7.09	C02-AWG16-4S
14AWG x 2C (0.0641/1.63)	Solid	2.09	8.45	0.240 / 6.10	C02-AWG14-2
14AWG x 4C (0.0641/1.63)	Solid	2.09	8.45	0.283 / 7.19	C02-AWG14-4
14AWG x 2C (0.0508/1.87)	7-strand	2.75	8.60	0.275 / 6.99	C02-AWG14-2S
14AWG x 4C (0.0508/1.87)	7-stranded	2.75	8.60	0.325 / 8.24	C02-AWG14-4S
12AWG x 2C (0.0808/2.05)	Solid	3.30	5.31	0.269 / 6.83	C02-AWG12-2
12AWG x 2C (0.0808/2.37)	7-strand	4.41	5.41	0.311 / 7.90	C02-AWG12-2S

C02/

www.tpmcsteel.com

CF3000 range - Intelligent addressable control panel

Eaton's CF3000 is a high specification intelligent addressable control panel which is available in various loop configurations. These panels combine sophisticated functionality with simple operation and an aesthetically pleasing design.

The large capacity, ability to support complex cause and effect programming and wide range of user controllable functions make the system suitable for a diverse range of projects from sheltered housing to large office developments.

The CF3000 uses soft addressing to minimise installation time and remove the potential for error associated with manual addressing. It can operate as a stand alone panel or as part of a networked system. They have powerful programming options that allow configurable control over whether messages from specific panels are transmitted around the network or remain local.

An extensive range of compatible intelligent addressable systems ancillaries are available to work with the CF3000 all of which incorporate an integral short circuit isolator to provide maximum protection against short circuits on the external loop.

Features and benefits

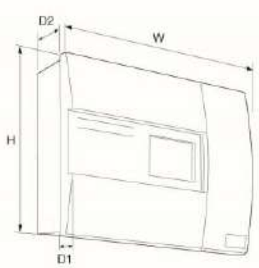
- Available in 1, 2 and 4 loop versions
- Up to 200 addresses per loop
- Full network capability up to 126 panels
- Event History Buffer (9,999 events) with Date/Time stamp
- Soft addressing
- Large versatile touch screen user interface
- Multi-language selection capability
- Integral printer (optional)
- Integral battery and power supply
- Flexible cause and effect programming
- Simple to operate end user touch-screen interface
- Flexible distributed network capability
- Full range of compatible accessories
- Easy to design system cause and effect using site installer software
- Full system integrity with Eaton's managed protocol

EATON Powering Business Worldwide

Technical specification

Code	CF30001G	CF30002G	CF30004G
Description	1 loop control panel	2 loop control panel	4 loop control panel
Standards	EN54 Pt2, 1997, A1:2006, EN54 Pt4, 1997, A1:2002, A2:2006 EN54 Pt13: 2005	EN54 Pt2, 1997, A1:2006, EN54 Pt4, 1997, A1:2002, A2:2006 EN54 Pt13: 2005	EN54 Pt2, 1997, A1:2006, EN54 Pt4, 1997, A1:2002, A2:2006 EN54 Pt13: 2005
Specification			
Number of loops	1	2	4
Addresses per loop	200	200	200
Number of conventional sounder circuits	4 monitored for open and short circuit	4 monitored for open and shortcircuit	4 monitored for open and short circuit
Auxiliary fire routing equipment output (monitored)	24V 30mA (max)	24V 30mA (max)	24V 30mA (max)
Auxiliary fire protection equipment output (monitored)	24V 30mA (max)	24V 30mA (max)	24V 30mA (max)
Auxiliary fault routing equipment output (monitored)	12V 30mA (max)	12V 30mA (max)	12V 30mA (max)
System operating voltage	24V dc (nom)	24V dc (nom)	24V dc (nom)
Mains input supply	230V ac +10% / -15%	230V ac +10% / -15%	230V ac +10% / -15%
Class change facility	Terminals for connection of external contacts, can also be instigated via input interface	Terminals for connection of external contacts, can also be instigated via input interface	Terminals for connection of external contacts, can also be instigated via input interface
Auxiliary relay	1 set of changeover contacts operate in event of fire condition	1 set of changeover contacts operate in event of fire condition	1 set of changeover contacts operate in event of fire condition
Output ports	RS485, RS232 for connection of repeaters etc	RS485, RS232 for connection of repeaters etc	RS485, RS232 for connection of repeaters etc
Standby duration	Dependant on loop loading and battery configuration	Dependant on loop loading and battery configuration	Dependant on loop loading and battery configuration
Battery	2 x 12Ah (standard versions)	2 x 12Ah (standard versions) 4 x 12Ah (EB versions)	2 x 12Ah (standard versions) 4 x 12Ah (EB versions)
Environmental			
Operating temperature	-5°C to +40°C	-5°C to +40°C	-5°C to +40°C
Humidity (non condensing)	0 to 75% RH	0 to 75% RH	0 to 75% RH
Physical			
Construction	Back box - mild steel, front door - PC/ABS	Back box - mild steel, front door - PC/ABS	Back box - mild steel, front door - PC/ABS
Dimensions (H x W x D)	Standard versions: 397mm x 497mm x 180mm	Standard versions: 397mm x 497mm x 180mm EB Versions: 397mm x 497mm x 280mm	Standard versions: 397mm x 497mm x 180mm EB Versions: 397mm x 497mm x 280mm
Weight	18kg	18kg	18kg
Ingress protection	IP30	IP30	IP30
Cable entries	Top: 31 cable knockouts (20mm) Back: 12 cable knockouts (20mm)	Top: 31 cable knockouts (20mm) Back: 12 cable knockouts (20mm)	Top: 31 cable knockouts (20mm) Back: 12 cable knockouts (20mm)
System networking	Fully networkable up to 126 panels (requires additional network card - 1 per panel)	Fully networkable up to 126 panels (requires additional network card - 1 per panel)	Fully networkable up to 126 panels (requires additional network card - 1 per panel)

Dimensions



Description	H (mm)	W (mm)	D1 (mm)	D2 (mm)
Standard	397	497	55	125
EB	397	497	55	225

Catalogue numbers

Description	Code
1 Loop control panel	CF30001G
1 Loop control panel, integral printer	CF30001GP
2 Loop control panel	CF30002G
2 Loop control panel, integral printer	CF30002GP
2 Loop control panel, extended battery	CF30002GEB
2 Loop control panel, integral printer, extended battery	CF30002GPEB
4 Loop control panel	CF30004G
4 Loop control panel, integral printer	CF30004GP
4 Loop control panel, extended battery	CF30004GEB
4 Loop control panel, integral printer, extended battery	CF30004GPEB
Add to end of product code if network card required	NC
Touch-screen repeater panel	CTPR3000
Passive repeater panel	CF3000PRG
Hinged protective cover kit	CF3000COV
Network kit (for retro fit)	DF6000NETKIT
Fire alarm system log book	MFALOG

SIGNALING
UL
LISTED
4AC5
FIRE ALARM
EQUIPMENT

HSR & HSWC Horn Strobes

HSWC - Horn Strobe, Ceiling Mounted

HSR - Horn Strobe, Wall Mounted

Overview

The UL range of notification devices are designed to exceed your expectations and offer the most polished, feature rich and cost effective solution.

Both stylish and inspiring, architects and engineers can now specify the industry's sleekest looking fire notification appliance, while being afforded all the features and benefits that provide the industry's lowest total cost of ownership.

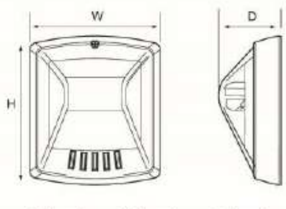
Features

- **80% reduction in SKUs - Up to 9 models now in 1 appliance**
- 3 audible settings
- 8 candela settings in 1 device
  Wall - 15/1575/30/75/95/110/135/185
  Ceiling - 15/30/60/75/95/115/150/177
- A combination of 12 and 24 VDC in one appliance providing the capability to use a single appliance for different installation requirements
- A universal, common base for retrofit jobs, limited space environments and pre-existing wire configurations. It comes complete with a Contact Cover for protection against dirt, dust, paint and damage to the contacts. The Contact Cover also acts as a shunting device to allow pre-wire testing for common wiring issues.

Benefits

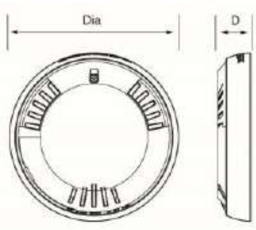
- Up to 48% savings in current draw over similar products, with the latest horn/strobe products you can install more appliances per a given circuit.
- A combination of 12 and 24 VDC in one appliance
- **Easier to install - Save up to 14% cost of installation****
- 5 Mounting Options - 1 gang, 2 gang, 4"sq., 3.5 octal, 4" octal box
- Voltage test points for quick troubleshooting and easy spot checking
- 1/16" deep mounting error relief Pre-wire capability to check for wiring & ground faults prior to appliance installation
- Contact cover not only provides protection from dirt, dust, paint and accidental damage, it allows for pre-wire testing and troubleshooting

Dimensions - Wall



H (mm)	W (mm)	D (mm)
133	116	56

Dimensions - Ceiling



Dia (mm)	D (mm)
166	34

All strobe models are UL dual listed - meeting both UL1638 and UL1971 requirements. As dual listed appliances, these weatherproof strobes are listed for outdoor applications under UL 1638 as well as under UL 1971, the Standard for Safety Signaling Devices for Hearing Impaired. With an extended temperature range of -31°F to 150°F (-40°C to 66°C), the weatherproof appliances meet or exceed UL outdoor test requirements for rain, humidity and corrosion resistance while providing multiple strobe intensity options, including the highest strobe ratings available for area coverage per NFPA 72 strobe spacing tables (up to 185 candela for wall mounting and 177 candela for ceiling mounting).

Technical Specification

Code	HSR	HSWC
Description	Horn Strobes, Wall Mounted	Horn Strobes, Ceiling Mounted
Standards	UL Standard 464	UL Standard 464
Opperation		
12/24 Vdc	15/1575/30/75/95/110/135/185 cd, 90/95/99 dB(A)	15/30/60/75/95/115/150/177 cd, 90/95/99 dB(A)
Environmental		
Operating Temperature	0°C to 49°C	0°C to 49°C
Humidity (Non Condensing)	0 to 93 %RH	0 to 93 %RH
Compatibility		
Suitable for use with	Cooper UL fire systems	Cooper UL fire systems

Horn Strobe Ratings

Horn Strobe Ratings per UL 1971 & UL 464 at 24 Vdc

		UL Max Current* at 99 dB(A)													
		24 V dc												12 V dc	
Mode	Regulated Voltage Range V dc	15	15/75	30	60	75	95	110	115	135	150	177	185	15	15/75
HS	8.0-33.0	0.082	0.095	0.102		0.148	0.176	0.197		0.242			0.282	0.125	0.159
HSC	8.0-33.0	0.082		0.102	0.141	0.148	0.176		0.197		0.242	0.282		0.125	

Horn Strobe Ratings per UL 1971 & UL 464 at 24 V dc

		UL Max Current* at 95 dB(A)													
		24 V dc												12 V dc	
Mode	Regulated Voltage Range V dc	15	15/75	30	60	75	95	110	115	135	150	177	185	15	15/75
HS	8.0-33.0	0.073	0.083	0.087		0.139	0.163	0.186		0.230			0.272	0.122	0.153
HSC	8.0-33.0	0.073		0.087	0.128	0.139	0.163		0.186		0.230	0.272		0.122	

Horn Strobe Ratings per UL 1971 & UL 464 at 24 V dc

		UL Max Current* at 90 dB(A)													
		24 V dc												12 Vdc	
Mode	Regulated Voltage Range V dc	15	15/75	30	60	75	95	110	115	135	150	177	185	15	15/75
HS	8.0-33.0	0.065	0.075	0.084		0.136	0.157	0.184		0.226			0.267	0.120	0.148
HSC	8.0-33.0	0.065		0.084	0.120	0.136	0.157		0.184		0.226	0.267		0.120	

Product Codes

Code	Description
HSR	Horn Strobe, Wall Mount, Snap Base, 153075100cd up to 105 dB @ 1meter
HSWC	Horn Strobe, Ceiling Mount, Snap Base, 153075100cd up to 105 dB @ 1meter

CSC354 - Intelligent addressable 4 way sounder controller unit

An extensive range of interfaces are available to support Eaton's range of control panels, providing solutions for most design requirements.

The 4 way sounder controller unit (CSC354) is a loop connected interface, which provides the facility to power and control 4 independent conventional sounder circuits. This greatly simplifies installation in applications where specialist sounders or beacons are required by avoiding the need to connect them directly to the intelligent addressable control panel.

This unit only uses a single address yet each circuit can be independently controlled according to the required cause and effect programming.

Features and benefits

- Soft addressed
- Integral short circuit isolator
- Single address
- 4 Separate sounder circuit outputs (total 1.6A max)
- Avoids the need to wire conventional sounders back to the control panel
- Outputs are independently programmable (delays on circuit 1 only)
- Integral battery and power supply
- Quick and simple to install
- No hard addressing required (Plug and play)
- Increased system integrity
- Beacons and strobes can be wired direct to the interface (saving on both time and installation)

EATON
Powering Business Worldwide

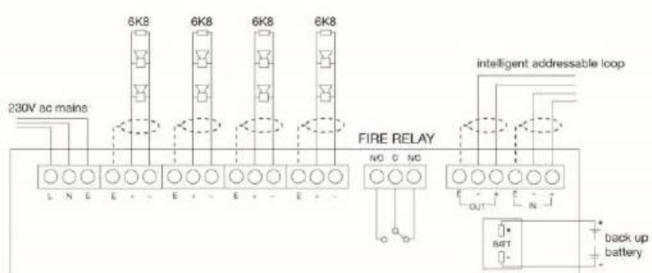
Technical specification

Code	CSC354
Description	4 way sounder controller unit
Specification	
Operating voltage	24V dc
Quiescent current	310µA
Mains supply voltage	230V ac
Mains current consumption	0.4A
Battery	2 x 12 V, 4Ah, SLA
Standby period	24 hours + 30 minutes ringing
Sounder circuit output	0.8A (max), single circuit
Sounder load	3.2A (max), total
Fire relay switching voltage	30V dc
Switching current	1A (resistive), 0.5A (inductive) (max)
Environmental	
Operating temperature	-10°C to +45°C
Humidity (non condensing)	0 to 95% RH
Physical	
Construction	ABS/Steel
Dimensions (H x W x D)	300mm x 300mm x 74mm
Weight	5.4kg
Ingress protection	IP30
Compatibility	
Suitable for use with	Eaton intelligent addressable fire systems

Installation

1. The sounder controller interface requires a local unswitched 230V supply and incorporates a back up battery to maintain functionality under mains failure conditions
2. Cable entry can be top or rear
3. Top entry is via 20mm conduit entries (pre-fitted with blanking plugs for unused entries)
4. Rear entry via substantial cable slot in metal back plate
5. Top cover secured with tamper resistant screws

Standard connections



NOTES:
1. Earth (Screen) cable must be connected to its adjacent earth terminal.
2. The end of line resistor must always be fitted, even if input is not used.
3. Sounder circuits are monitored for wiring open and short circuit.
4. Output fire relay is a set of changeover volt free-contacts and is not monitored.
5. This unit should only be finally connected to the 230V ac mains supply and battery, during system commissioning.

Catalogue numbers

Description	Code
4 way sounder controller unit	CSC354

ULMCOM - UL micro single channel output unit

SIGNALING
LISTED
4AC5
FIRE ALARM
EQUIPMENT

An extensive range of interfaces are available to support the Eaton range of UL intelligent addressable control panels, providing solutions for most design requirements.

The UL single channel output unit (ULMCOM) is an extremely compact unit ideal for incorporation in to external equipment and suitable for switching low voltages (24V dc at 1A maximum).

This unit incorporates a set of non latching relay contacts and is suitable for switching HVAC control circuits, plant shutdown control circuits, fire door closure etc.

The ULMCOM is identified by the panel as an input / output unit, with a maximum of 20 units permitted per loop.

Features and benefits

- Soft addressed
- Integral short circuit isolator
- Single address
- Non latching changeover relay contacts
- Suitable for switching low volts control gear
- Optional variant: ULMCOM-S
- Quick and simple to install
- No hard addressing required (plug and play)
- Compact size

Optional variant

The ULMCOM-S is identified by the panel as a sounder and resets on silence. The maximum number of ULMCOM-S units per loop is 60, and is counted towards the total number of sounders on the loop.

EATON
Powering Business Worldwide

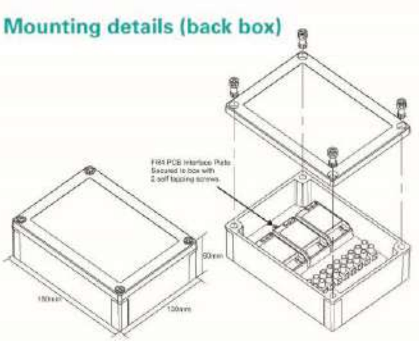
Specifier's guide
3.6 Micro interfaces

Technical specification

Code	ULMCOM and ULMCOM-S
Description	Single channel output units
Standards	UL864 9th edition
Signalling line circuit (Style 7, Class A, Supervised, Power Limited)	
Current	0.322mA (max)
Output relay (supervisory programmable)	
Switching voltage	24V dc to 30V dc
Contact rating	1A Resistive, pf=1 (max)
Max line impedance	16Ω
Power factor	1
Environmental	
Operating temperature	0°C to 49°C
Humidity (non condensing)	0 to 93 %RH
Physical	
Dimensions (H x W x D)	65mm x 35mm x 18.5mm
Weight	0.05kg
Ingress protection	IP40
Compatibility	
Suitable for use with	Eaton UL fire systems

Notes:
No addressing of the interface is required (see control panel operation for details).

Mounting details (back box)



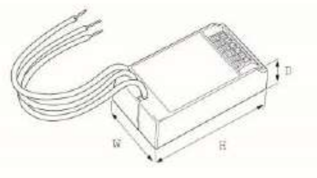
Installation

1. Fit the unit in position in accordance to the mounting details.
2. Connect the unit according to standard connections.
3. Up to 3 units can be fitted inside a micro module box unit.

Operation

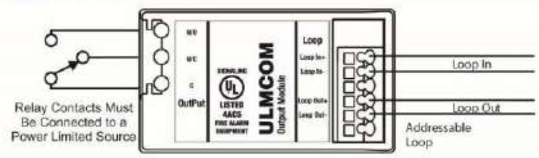
Normal standby / alarm

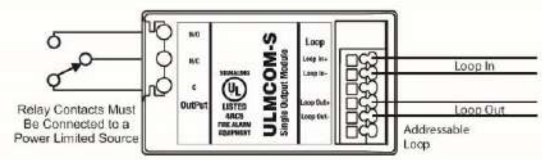
Dimensions



H (mm)	W (mm)	D (mm)
65	35	18.5

Standard connections





Notes:
1. Output relay are volt-free contacts and are not monitored.
2. Recommended cable type FPLP (plenum cable), type FPLR (riser cable), or type FPL.

Description	SLC field wiring (input)	Single channel output
Wiring gauge	12 Max AWG	12 Max AWG
Wiring class	Class A, Style 7	-
Ground fault impedance	0.1Ω	-
Supervised, power limited	Yes	Yes

Catalogue numbers

Description	Code
Micro single channel output unit (recognised as output unit)	ULMCOM
Micro single channel output unit (recognised as sounder)	ULMCOM-S
Micro module box unit (empty box)	ULBU

Appendix-10: Sprinkler Catalog

tyco®

Worldwide Contacts | www.tyco-fire.com

Series TY-FRB – 2.8, 4.2, 5.6, and 8.0 K-Factor Upright, Pendent, and Recessed Pendent Sprinklers Quick Response, Standard Coverage

General Description

The TYCO Series TY-FRB 2.8, 4.2, 5.6, and 8.0 K-factor Upright, Pendent, and Recessed Pendent Sprinklers described in herein are quick response, standard coverage, decorative 3 mm glass bulb-type spray sprinklers. They are designed for use in light or ordinary hazard, commercial occupancies such as banks, hotels, and shopping malls.

The TY-FRB Recessed Pendent Sprinkler, where applicable, is intended for use in areas with a finished ceiling. This recessed pendent sprinkler uses one of the following Recessed Escutcheons:

- A two-piece Style 10 (1/2 in. NPT) or Style 40 (3/4 in. NPT) Recessed Escutcheon with 1/2 in. (12,7 mm) of recessed adjustment or up to 3/4 in. (19,1 mm) of total adjustment from the flush pendent position.
- A two-piece Style 20 (1/2 in. NPT) or Style 30 (3/4 in. NPT) Recessed Escutcheon with 1/4 in. (6,4 mm) of recessed adjustment or up to 1/2 in. (12,7 mm) of total adjustment from the flush pendent position.

The adjustment provided by the Recessed Escutcheon reduces the accuracy to which the fixed pipe drops to the sprinklers must be cut.

Corrosion-resistant coatings, where applicable, are utilized to extend the life of copper alloy sprinklers beyond what would be obtained when exposed to corrosive atmospheres. Although corrosion-resistant coated sprinklers have passed the standard corrosion tests of the applicable approval agencies, the testing is not representative of all possible corrosive atmospheres. Consequently, it is recommended that the end user be consulted with respect to the suitability of these coatings for any given corrosive environment. The effects of ambient temperature, concentration of chemicals, and gas/chemical velocity, should be considered, as a minimum, along with the corrosive nature of the chemical to which the sprinklers will be exposed.

An intermediate level version of the Series TY-FRB Pendent Sprinklers is detailed in Technical Data Sheet TFP356. Sprinkler Guards are detailed in Technical Data Sheet TFP780.

IMPORTANT

Refer to Technical Data Sheet TFP2300 for warnings pertaining to regulatory and health information.

Always refer to Technical Data Sheet TFP700 for the "INSTALLER WARNING" that provides cautions with respect to handling and installation of sprinkler systems and components. Improper handling and installation can permanently damage a sprinkler system or its components and cause the sprinkler to fail to operate in a fire situation or cause it to operate prematurely.

NOTICE

The Series TY-FRB 2.8, 4.2, 5.6, and 8.0 K-factor Upright, Pendent, and Recessed Pendent Sprinklers described herein must be installed and maintained in compliance with this document and with the applicable standards of the National Fire Protection Association (NFPA), in addition to the standards of any authorities having jurisdiction. Failure to do so may impair the performance of these devices.

The owner is responsible for maintaining their fire protection system and devices in proper operating condition. The installing contractor or sprinkler manufacturer should be contacted with any questions.

NFPA 13 prohibits installation of 1/2 in. NPT sprinklers with K-factors greater than 5.6 in new construction. They are intended for retrofit in existing sprinkler systems only.

Sprinkler Identification Number (SIN)

TY1131 . . . Upright 2.8K, 1/2 in. NPT
TY1231 . . Pendent 2.8K, 1/2 in. NPT
TY2131 . . . Upright 4.2K, 1/2 in. NPT
TY2231 . . Pendent 4.2K, 1/2 in. NPT
TY3131 . . . Upright 5.6K, 1/2 in. NPT
TY3231 . . Pendent 5.6K, 1/2 in. NPT
TY4131 . . . Upright 8.0K, 3/4 in. NPT
TY4231 . . Pendent 8.0K, 3/4 in. NPT
TY4831 . . . Upright 8.0K, 1/2 in. NPT
TY4931 . . Pendent 8.0K, 1/2 in. NPT

Technical Data

Approvals
UL and C-UL Listed
FM, LPCB, and NYC Approved

See Tables A, B, C and D for complete approval information including corrosion-resistant status.

Maximum Working Pressure
See Table E

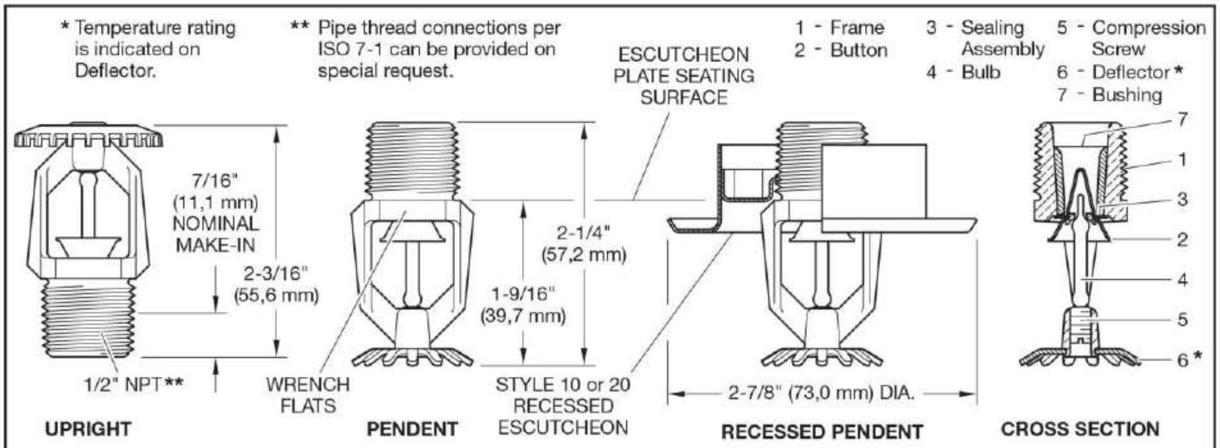


FIGURE 1
QUICK RESPONSE SERIES TY-FRB UPRIGHT (TY1131) AND PENDENT (TY1231) SPRINKLERS
2.8 K-FACTOR, 1/2 IN. NPT

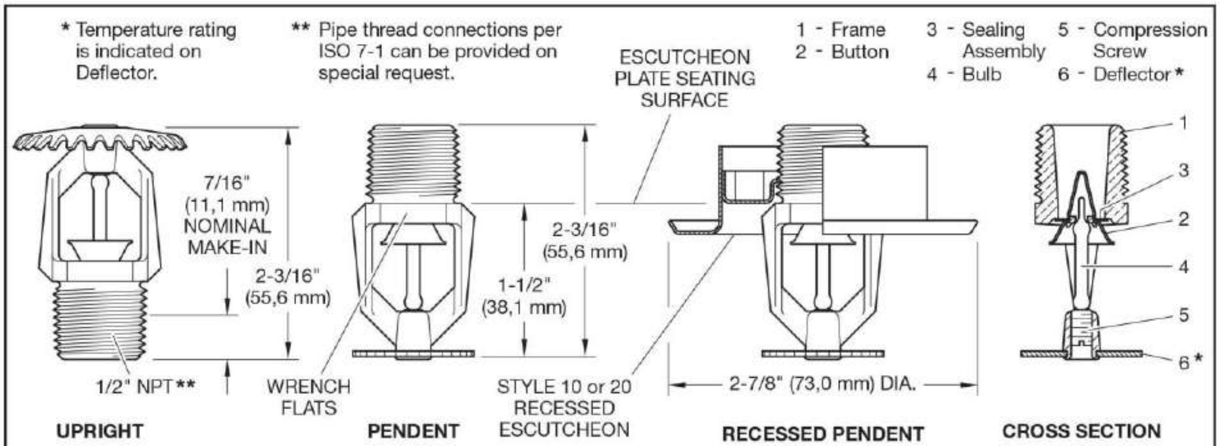


FIGURE 2
QUICK RESPONSE SERIES TY-FRB UPRIGHT (TY2131) AND PENDENT (TY2231) SPRINKLERS
4.2 K-FACTOR, 1/2 IN. NPT

Discharge Coefficient
K=2.8 GPM/psi$^{1/2}$ (40,3 LPM/bar$^{1/2}$)
K=4.2 GPM/psi$^{1/2}$ (60,5 LPM/bar$^{1/2}$)
K=5.6 GPM/psi$^{1/2}$ (80,6 LPM/bar$^{1/2}$)
K=8.0 GPM/psi$^{1/2}$ (115,2 LPM/bar$^{1/2}$)

Temperature Rating
See Tables A and B

Finishes
Sprinkler: See Table D

Recessed Escutcheon: Signal or Pure White, Grey Aluminum, Jet Black, Chrome Plated, or Natural Brass

Physical Characteristics
Frame . . . . .Bronze
Button . . . . .Brass/Copper
Sealing Assembly . .Beryllium Nickel w/TEFLON
Bulb. . . . . .Glass
Compression Screw . . . . .Bronze
Deflector .Copper/Bronze
Bushing (K=2.8) .Bronze

Poly-Stainless Physical Characteristics
Frame . . . . .Bronze
Button . . . . L316 Stainless Steel*
Bulb. . . . . .Glass
Compression Screw . . . . . L316 Stainless Steel*
Deflector . . . . .Copper/Bronze
Sealing Assembly . Gold Plated Beryllium Nickel w/TEFLON

*Type L316 stainless steel (UNS 31603) per ASTM A479/479M or BS EN 1008 WN1.4404.

Operation
The glass bulb contains a fluid that expands when exposed to heat. When the rated temperature is reached, the fluid expands sufficiently to shatter the glass bulb, allowing the sprinkler to activate and water to flow.

Design Criteria
The TYCO Series TY-FRB 2.8, 4.2, 5.6, and 8.0 K-factor Upright, Pendent, and Recessed Pendent Sprinklers are intended for fire protection systems designed in accordance with the standard installation rules recognized by the applicable Listing or Approval agency, such as UL Listing based on the requirements of NFPA 13 and FM Approval based on the requirements of the FM Global Loss Prevention Data Sheets. Use only the style 10, 20, 30, or 40 Recessed Escutcheon, as applicable, for recessed pendent installations.

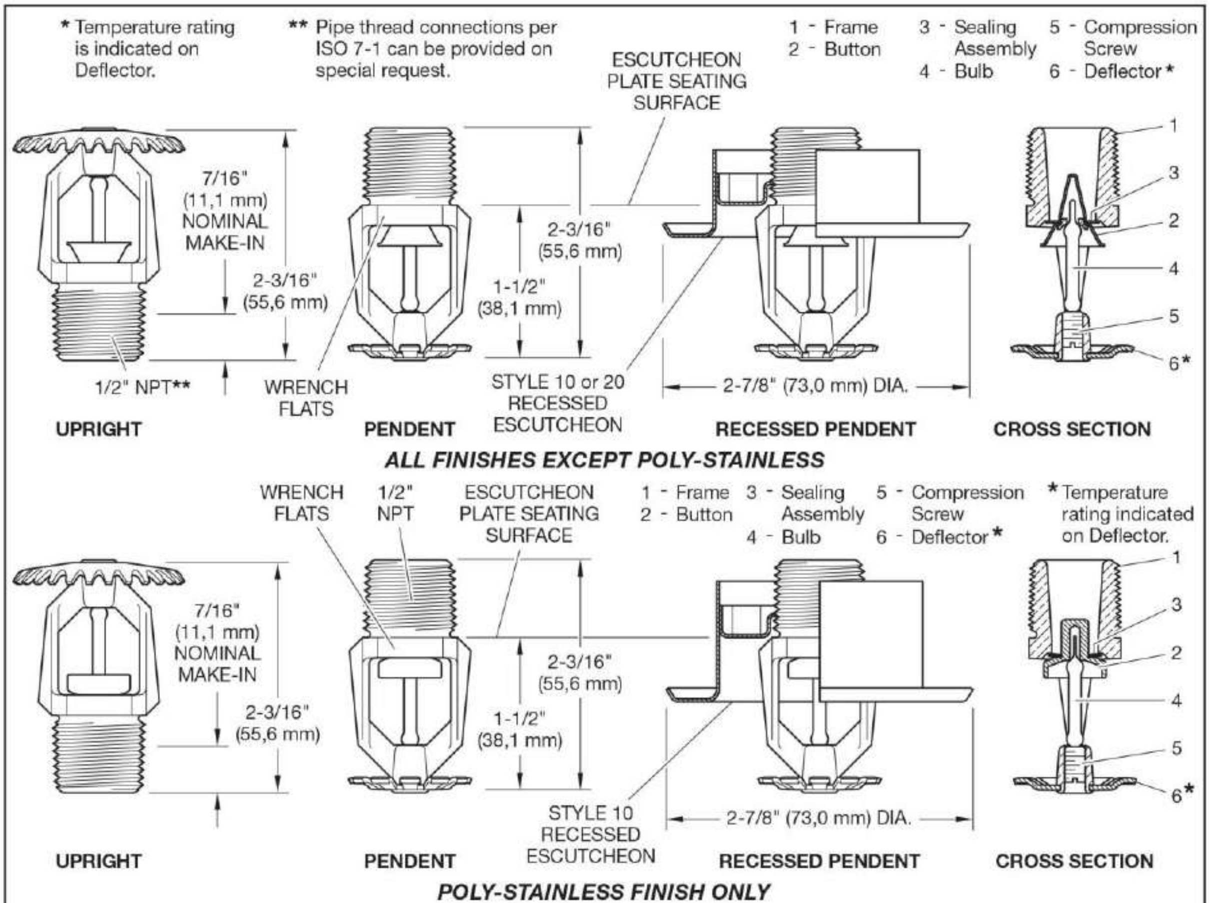


FIGURE 3
QUICK RESPONSE SERIES TY-FRB UPRIGHT (TY3131) AND PENDENT (TY3231) SPRINKLERS
5.6 K-FACTOR, 1/2 IN. NPT

Installation

The TYCO Series TY-FRB 2.8, 4.2, 5.6, and 8.0 K-factor Upright, Pendent, and Recessed Pendent Sprinklers must be installed in accordance with this section.

General Instructions
Do not install any bulb type sprinkler if the bulb is cracked or there is a loss of liquid from the bulb. With the sprinkler held horizontally, a small air bubble should be present. The diameter of the air bubble is approximately 1/16 in. (1,6 mm) for the 135°F (57°C) and 3/32 in. (2,4 mm) for the 286°F (141°C) temperature ratings. A leak-tight 1/2 in. NPT sprinkler joint should be obtained by applying a minimum-to-maximum torque of 7 to 14 lb-ft (9,5 to 19,0 N·m). A leak tight 3/4 in. NPT sprinkler joint should be obtained with a torque of 10 to 20 lb-ft (13,4 to 26,8 N·m). Higher levels of torque can distort the sprinkler inlet and cause leakage or impairment of the sprinkler. Do not attempt to compensate for insufficient adjustment in the escutcheon plate by under- or over-tightening the sprinkler. Re-adjust the position of the sprinkler fitting to suit.

Series TY-FRB Upright and Pendent Sprinklers
The Series TY-FRB Upright and Pendent Sprinklers must be installed in accordance with the following instructions:

Step 1. Install pendent sprinklers in the pendent position. Install upright sprinklers in the upright position.

Step 2. With pipe thread sealant applied to the pipe threads, hand-tighten the sprinkler into the sprinkler fitting.

Step 3. Tighten the sprinkler into the sprinkler fitting using only the W-Type 6 Sprinkler Wrench (Ref. Figure 14). With reference to Figure 1 to Figure 5, apply the W-Type 6 Sprinkler Wrench to the sprinkler wrench flats.

Series TY-FRB Recessed Pendent Sprinklers
The Series TY-FRB Recessed Pendent Sprinklers must be installed in accordance with the following instructions:

Step 1. After installing the Style 10, 20, 30, or 40 Mounting Plate, as applicable, over the sprinkler threads and with pipe-thread sealant applied to the pipe threads, hand-tighten the sprinkler into the sprinkler fitting.

Step 2. Tighten the sprinkler into the sprinkler fitting using only the W-Type 7 Recessed Sprinkler Wrench, see Figure 15. With reference to Figure 1 to 4, apply the W-Type 7 Recessed Sprinkler Wrench to the sprinkler wrench flats.

Step 3. After the ceiling is installed or the finish coat is applied, slide on the Style 10, 20, 30, or 40 Closure over the Series TY-FRB Recessed Pendent Sprinkler and push the Closure over the Mounting Plate until its flange comes in contact with the ceiling.

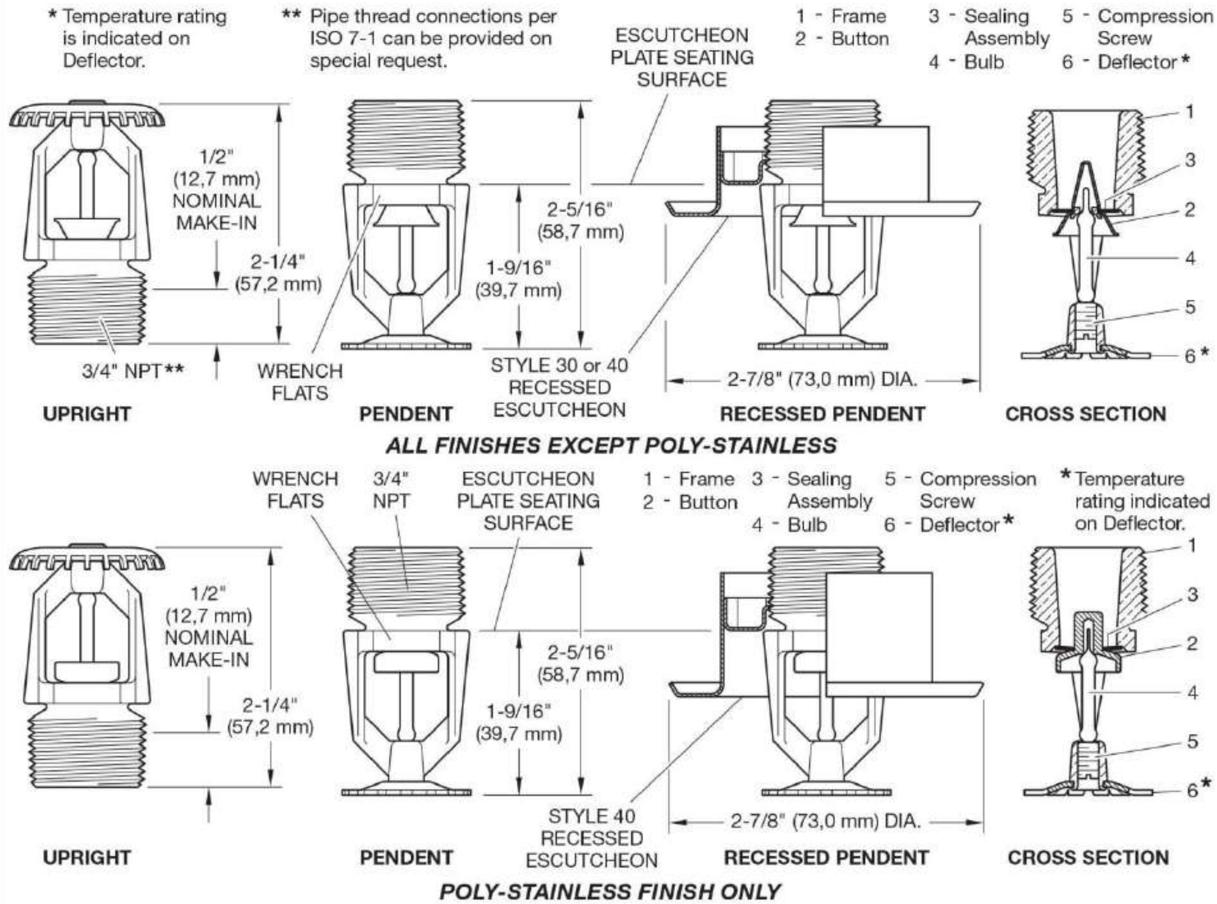


FIGURE 4
QUICK RESPONSE SERIES TY-FRB UPRIGHT (TY4131) AND PENDENT (TY4231) SPRINKLERS
8.0 K-FACTOR, 3/4 IN. NPT

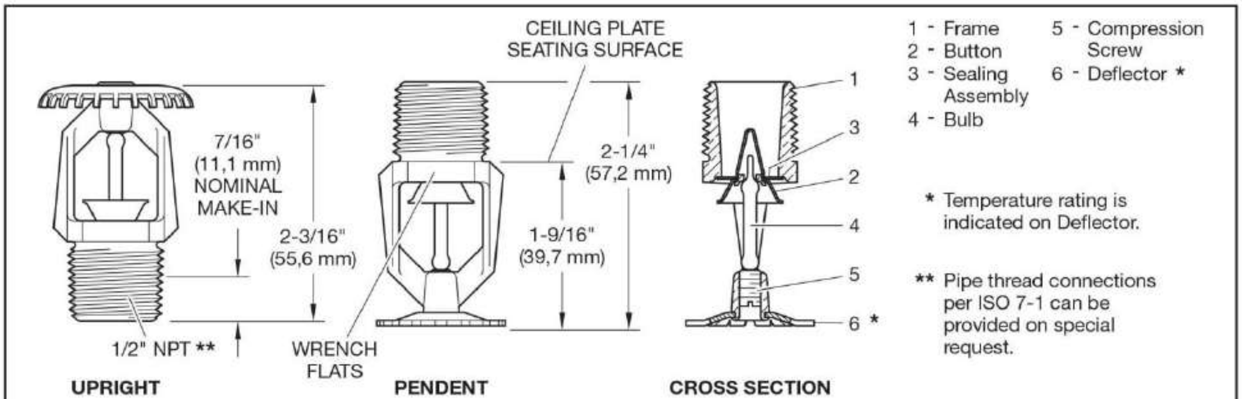


FIGURE 5
QUICK RESPONSE SERIES TY-FRB UPRIGHT (TY4831) AND PENDENT (TY4931) SPRINKLERS
8.0 K-FACTOR, 1/2 IN. NPT

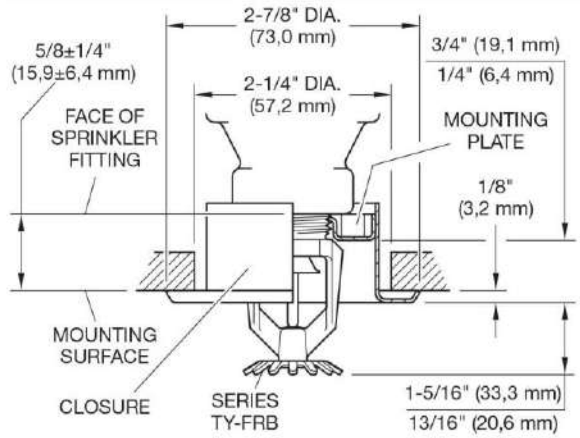


FIGURE 6
SERIES TY-FRB RECESSED PENDENT
WITH TWO-PIECE 3/4 INCH TOTAL ADJUSTMENT
STYLE 10 RECESSED ESCUTCHEON
2.8 K-FACTOR, 1/2 IN. NPT

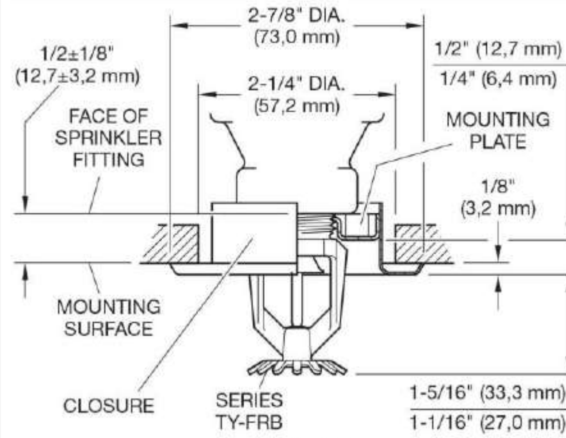


FIGURE 7
SERIES TY-FRB RECESSED PENDENT
WITH TWO-PIECE 1/2 INCH TOTAL ADJUSTMENT
STYLE 20 RECESSED ESCUTCHEON
2.8 K-FACTOR, 1/2 IN. NPT

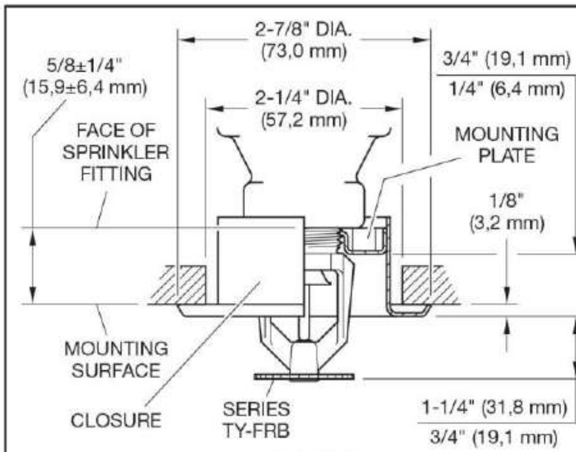


FIGURE 8
SERIES TY-FRB RECESSED PENDENT
WITH TWO-PIECE 3/4 INCH TOTAL ADJUSTMENT
STYLE 10 RECESSED ESCUTCHEON
4.2 K-FACTOR, 1/2 IN. NPT

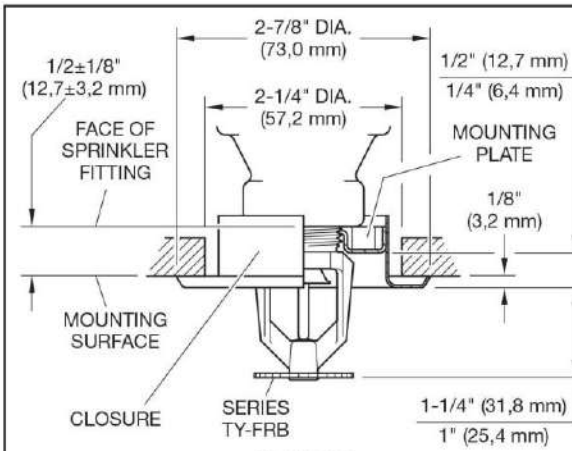


FIGURE 9
SERIES TY-FRB RECESSED PENDENT
WITH TWO-PIECE 1/2 INCH TOTAL ADJUSTMENT
STYLE 20 RECESSED ESCUTCHEON
4.2 K-FACTOR, 1/2 IN. NPT

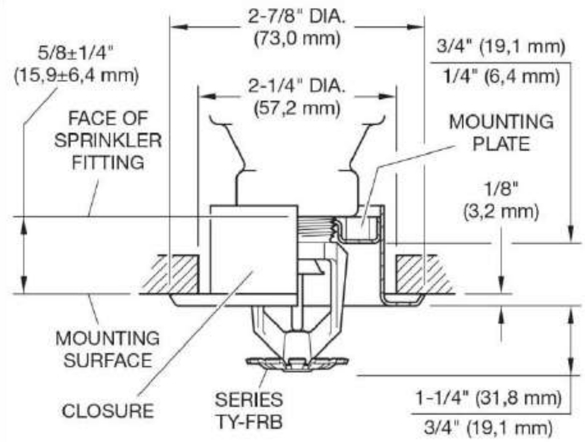


FIGURE 10
SERIES TY-FRB RECESSED PENDENT
WITH TWO-PIECE 3/4 INCH TOTAL ADJUSTMENT
STYLE 10 RECESSED ESCUTCHEON
5.6 K-FACTOR, 1/2 IN. NPT

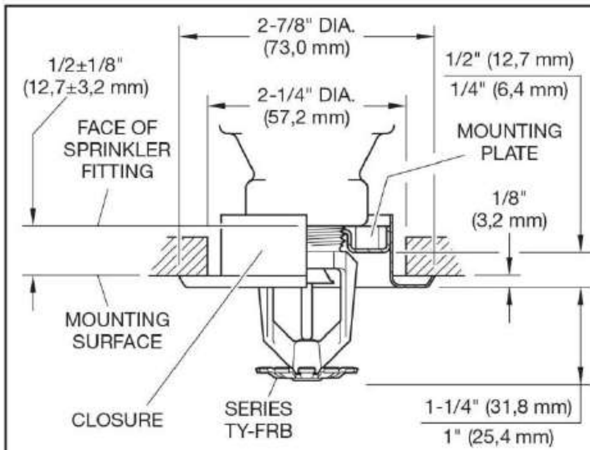


FIGURE 11
SERIES TY-FRB RECESSED PENDENT
WITH TWO-PIECE 1/2 INCH TOTAL ADJUSTMENT
STYLE 20 RECESSED ESCUTCHEON
5.6 K-FACTOR, 1/2 IN. NPT

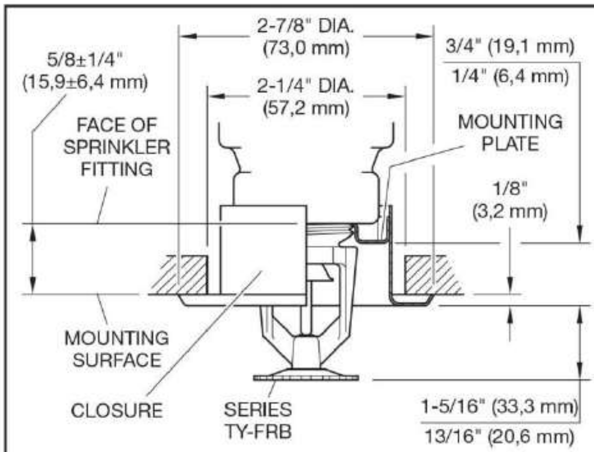


FIGURE 12
SERIES TY-FRB RECESSED PENDENT
WITH TWO-PIECE 3/4 INCH TOTAL ADJUSTMENT
STYLE 40 RECESSED ESCUTCHEON
8.0 K-FACTOR, 3/4 IN. NPT

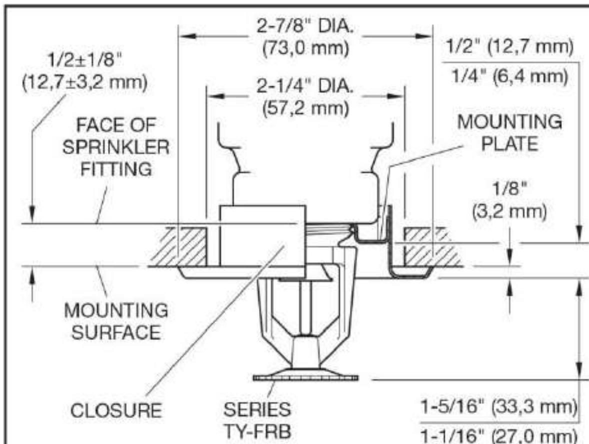


FIGURE 13
SERIES TY-FRB RECESSED PENDENT
WITH TWO-PIECE 1/2 INCH TOTAL ADJUSTMENT
STYLE 30 RECESSED ESCUTCHEON
8.0 K-FACTOR, 3/4 IN. NPT

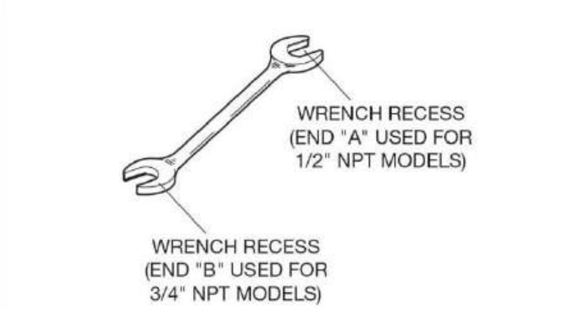


FIGURE 14
W-TYPE 6 SPRINKLER
WRENCH

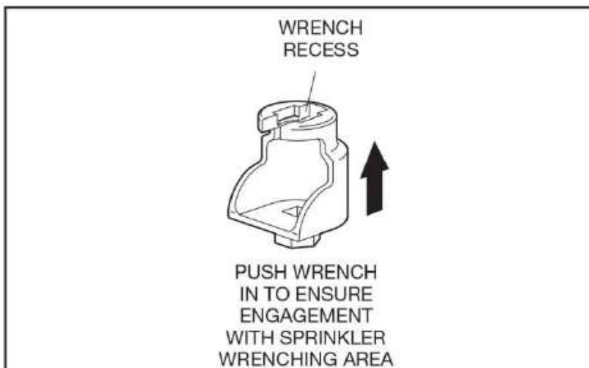


FIGURE 15
W-TYPE 7 RECESSED
SPRINKLER WRENCH

K-Factor	Type	Temperature	Bulb Liquid Color	Sprinkler Finish[5]		
				Natural Brass	Chrome Plated	Polyester[c]
2.8 1/2 in. NPT	Pendent (TY1231)	135°F (57°C)	Orange	1, 2, 3, 4		
		155°F (68°C)	Red			
		175°F (79°C)	Yellow			
		200°F (93°C)	Green			
		286°F (141°C)	Blue			
	Upright (TY1131)	135°F (57°C)	Orange			
		155°F (68°C)	Red			
		175°F (79°C)	Yellow			
		200°F (93°C)	Green			
		286°F (141°C)	Blue			
	Recessed Pendent (TY1231)[a] Figure 6	135°F (57°C)	Orange	1, 2, 4		
		155°F (68°C)	Red			
		175°F (79°C)	Yellow			
		200°F (93°C)	Green			
	Recessed Pendent (TY1231)[b] Figure 7	135°F (57°C)	Orange			
		155°F (68°C)	Red			
		175°F (79°C)	Yellow			
		200°F (93°C)	Green			

NOTES

a. Installed with Style 10 (1/2 in. NPT) or Style 40 (3/4 in. NPT) 3/4 in. Total Adjustment Recessed Escutcheon, as applicable.
b. Installed with Style 20 (1/2 in. NPT) or Style 30 (3/4 in. NPT) 1/2 in. Total Adjustment Recessed Escutcheon, as applicable.
c. Frame and Deflector only.
1. Listed by Underwriters Laboratories, Inc., (UL) as Quick Response Sprinklers.
2. Listed by Underwriters Laboratories, Inc., for use in Canada (C-UL) as Quick Response Sprinklers.
3. Approved by Factory Mutual Research Corporation (FM) as Quick Response Sprinklers.
4. Approved by the City of New York under MEA 354-01-E.
5. Where Polyester Coated Sprinklers are noted to be UL and C-UL Listed, the sprinklers are UL and C-UL Listed, the sprinklers are UL and C-UL Listed as corrosion-resistant sprinklers.

TABLE A
LABORATORY LISTINGS AND APPROVALS FOR 2.8 K-FACTOR SPRINKLERS

K-Factor	Type	Temperature	Bulb Liquid Color	Sprinkler Finish[8]				
				Natural Brass	Chrome Plated	Polyester[c]	Poly-Stainless[c]	Lead Coated
5.6 1/2 in. NPT	Pendent (TY3231)	135°F (57°C)	Orange	1, 2, 3, 4, 5, 6, 7			1, 2	1, 2, 3, 5
		155°F (68°C)	Red					
		175°F (79°C)	Yellow					
		200°F (93°C)	Green					
		286°F (141°C)	Blue					
	Upright (TY3131)	135°F (57°C)	Orange	1, 2, 3, 5, 6			1, 2	1, 2, 3, 5
		155°F (68°C)	Red					
		175°F (79°C)	Yellow					
		200°F (93°C)	Green					
		286°F (141°C)	Blue					
	Recessed Pendent (TY3231)[a] Figure 10	135°F (57°C)	Orange	1, 2, 4, 5			1, 2	N/A[d]
		155°F (68°C)	Red					
		175°F (79°C)	Yellow					
		200°F (93°C)	Green					
		286°F (141°C)	Blue					
	Recessed Pendent (TY3231)[b] Figure 11	135°F (57°C)	Orange	1, 2, 3, 4, 5			N/A	N/A
		155°F (68°C)	Red					
		175°F (79°C)	Yellow					
		200°F (93°C)	Green					
		286°F (141°C)	Blue					

NOTES

a. Installed with Style 10 (1/2 in. NPT) or Style 40 (3/4 in. NPT) 3/4 in. Total Adjustment Recessed Escutcheon, as applicable.
b. Installed with Style 20 (1/2 in. NPT) or Style 30 (3/4 in. NPT) 1/2 in. Total Adjustment Recessed Escutcheon, as applicable.
c. Frame and Deflector only.
d. Not available (N/A).
1. Listed by Underwriters Laboratories, Inc., (UL) as Quick Response Sprinklers.
2. Listed by Underwriters Laboratories, Inc., for use in Canada (C-UL) as Quick Response Sprinklers.
3. Approved by Factory Mutual Research Corporation (FM) as Quick Response Sprinklers.
4. Approved by the Loss Prevention Certification Board (LPCB Ref. No. 007k/04) as Quick Response Sprinklers. However, LPCB does not rate the thermal sensitivity of recessed sprinklers.
5. Approved by the City of New York under MEA 354-01-E.
6. VdS Approved (For details, contact Johnson Controls, Enschede, Netherlands, Tel. 31-53-428-4444/Fax 31-53-428-3377.)
7. Approved by the Loss Prevention Certification Board (LPCB Ref. No. 094a/06) as Quick Response Sprinklers.
8. Where Polyester Coated and Lead-Coated Sprinklers are noted to be UL and C-UL Listed, the sprinklers are UL and C-UL Listed as Corrosion-Resistant Sprinklers. Where Lead-Coated Sprinklers are noted to be FM Approved, the sprinklers are FM Approved as a Corrosion-Resistant Sprinklers.

TABLE C
LABORATORY LISTINGS AND APPROVALS FOR 5.6 K-FACTOR SPRINKLERS

<table>
<tr><th rowspan="2">K-Factor</th><th rowspan="2">Type</th><th rowspan="2">Temperature</th><th rowspan="2">Bulb Liquid Color</th><th colspan="5">Sprinkler Finish[8]</th></tr>
<tr><th>Natural Brass</th><th>Chrome Plated</th><th>Polyester[c]</th><th>Poly-Stainless[c]</th><th>Lead Coated</th></tr>
<tr><td rowspan="20">8.0
3/4 in.
NPT</td><td rowspan="5">Pendent
(TY4231)</td><td>135°F (57°C)</td><td>Orange</td><td rowspan="10" colspan="3">1, 2, 3, 4, 5, 6, 7</td><td rowspan="10">1, 2</td><td rowspan="10">1, 2, 5</td></tr>
<tr><td>155°F (68°C)</td><td>Red</td></tr>
<tr><td>175°F (79°C)</td><td>Yellow</td></tr>
<tr><td>200°F (93°C)</td><td>Green</td></tr>
<tr><td>286°F (141°C)</td><td>Blue</td></tr>
<tr><td rowspan="5">Upright
(TY4131)</td><td>135°F (57°C)</td><td>Orange</td></tr>
<tr><td>155°F (68°C)</td><td>Red</td></tr>
<tr><td>175°F (79°C)</td><td>Yellow</td></tr>
<tr><td>200°F (93°C)</td><td>Green</td></tr>
<tr><td>200°F (93°C)</td><td>Blue</td></tr>
<tr><td rowspan="5">Recessed
Pendent
(TY4231)[a]
Figure 12</td><td>135°F (57°C)</td><td>Orange</td><td rowspan="5" colspan="3">1, 2, 5</td><td rowspan="5">1, 2</td><td rowspan="5">N/A[d]</td></tr>
<tr><td>155°F (68°C)</td><td>Red</td></tr>
<tr><td>175°F (79°C)</td><td>Yellow</td></tr>
<tr><td>200°F (93°C)</td><td>Green</td></tr>
<tr><td>286°F (141°C)</td><td>Blue</td></tr>
<tr><td rowspan="5">Recessed
Pendent
(TY4231)[b]
Figure 13</td><td>135°F (57°C)</td><td>Orange</td><td rowspan="5" colspan="3">1, 2, 3, 5</td><td rowspan="5">N/A</td><td rowspan="5">N/A</td></tr>
<tr><td>155°F (68°C)</td><td>Red</td></tr>
<tr><td>175°F (79°C)</td><td>Yellow</td></tr>
<tr><td>200°F (93°C)</td><td>Green</td></tr>
<tr><td>286°F (141°C)</td><td>Blue</td></tr>
<tr><td rowspan="10">8.0
1/2 in.
NPT</td><td rowspan="5">Pendent
(TY4931)</td><td>135°F (57°C)</td><td>Orange</td><td rowspan="10" colspan="3">1, 2, 4, 5, 6</td><td rowspan="10">N/A</td><td rowspan="10">1, 2, 5</td></tr>
<tr><td>155°F (68°C)</td><td>Red</td></tr>
<tr><td>175°F (79°C)</td><td>Yellow</td></tr>
<tr><td>200°F (93°C)</td><td>Green</td></tr>
<tr><td>286°F (141°C)</td><td>Blue</td></tr>
<tr><td rowspan="5">Upright
(TY4831)</td><td>135°F (57°C)</td><td>Orange</td></tr>
<tr><td>155°F (68°C)</td><td>Red</td></tr>
<tr><td>175°F (79°C)</td><td>Yellow</td></tr>
<tr><td>200°F (93°C)</td><td>Green</td></tr>
<tr><td>286°F (141°C)</td><td>Blue</td></tr>
</table>

NOTES

a. Installed with Style 10 (1/2 in. NPT) or Style 40 (3/4 in. NPT) 3/4 in. Total Adjustment Recessed Escutcheon, as applicable.
b. Installed with Style 20 (1/2 in. NPT) or Style 30 (3/4 in. NPT) 1/2 in. Total Adjustment Recessed Escutcheon, as applicable.
c. Frame and Deflector only.
d. Not available (N/A).
1. Listed by Underwriters Laboratories, Inc., (UL) as Quick Response Sprinklers.
2. Listed by Underwriters Laboratories, Inc., for use in Canada (C-UL) as Quick Response Sprinklers.
3. Approved by Factory Mutual Research Corporation (FM) as Quick Response Sprinklers.
4. Approved by the Loss Prevention Certification Board (LPCB Ref. No. 007k/04) as Quick Response Sprinklers. However, LPCB does not rate the thermal sensitivity of recessed sprinklers.
5. Approved by the City of New York under MEA 354-01-E.
6. VdS Approved (For details, contact Johnson Controls, Enschede, Netherlands, Tel. 31-53-428-4444/Fax 31-53-428-3377.)
7. Approved by the Loss Prevention Certification Board (LPCB Ref. No. 094a/06) as Quick Response Sprinklers.
8. Where Polyester Coated and Lead-Coated Sprinklers are noted to be UL and C-UL Listed, the sprinklers are UL and C-UL Listed as Corrosion-Resistant Sprinklers. Where Lead-Coated Sprinklers are noted to be FM Approved, the sprinklers are FM Approved as a Corrosion-Resistant Sprinklers.

TABLE D
LABORATORY LISTINGS AND APPROVALS FOR 5.6 AND 8.0 K-FACTOR SPRINKLERS

<table>
<tr><th rowspan="2">K-Factor</th><th rowspan="2">Type</th><th colspan="4">Sprinkler Finish</th></tr>
<tr><th>Natural Brass</th><th>Chrome Plated</th><th>Polyester</th><th>Lead Coated</th></tr>
<tr><td rowspan="2">2.8
1/2 in.
NPT</td><td>Pendent (TY1231)
and
Upright (TY1131)</td><td colspan="3" rowspan="2">175 psi (12,1 bar)</td><td rowspan="2">N/A[2]</td></tr>
<tr><td>Recessed
Pendent (TY1231)</td></tr>
<tr><td rowspan="2">4.2
1/2 in.
NPT</td><td>Pendent (TY2231)
and
Upright (TY2131)</td><td colspan="3" rowspan="2">175 psi (12,1 bar)</td><td rowspan="2">N/A</td></tr>
<tr><td>Recessed
Pendent (TY2231)</td></tr>
<tr><td rowspan="2">5.6
1/2 in.
NPT</td><td>Pendent (TY3231)
and
Upright (TY3131)</td><td colspan="4" rowspan="2">250 psi (17,2 bar)
or 175 psi (12,1 bar)[1]</td></tr>
<tr><td>Recessed
Pendent (TY3231)</td></tr>
<tr><td rowspan="2">8.0
3/4 in.
NPT</td><td>Pendent (TY4231)
and
Upright (TY4131)</td><td colspan="3" rowspan="2">175 psi (12,1 bar)</td><td>175 psi
(12,1 bar)</td></tr>
<tr><td>Recessed
Pendent(TY4231)</td><td>N/A</td></tr>
<tr><td>8.0
1/2 in.
NPT</td><td>Pendent (TY4931)
and
Upright (TY4831)</td><td colspan="3">175 psi (12,1 bar)</td><td>175 psi
(12,1 bar)</td></tr>
</table>

NOTES
1. The maximum working pressure of 250 psi (17,2 bar) only applies to the Listing by Underwriters Laboratories Inc. (UL); the Listing by Underwriters Laboratories, Inc. for use in Canada (C-UL); and, the Approval by the City of New York.
2. Not available (N/A).

TABLE E
MAXIMUM WORKING PRESSURE

Care and Maintenance

The TYCO Series TY-FRB 2.8, 4.2, 5.6, and 8.0 K-factor Upright, Pendent, and Recessed Pendent Sprinklers must be maintained and serviced in accordance with this section. Before closing a fire protection system main control valve for maintenance work on the fire protection system that it controls, obtain permission to shut down the affected fire protection systems from the proper authorities and notify all personnel who may be affected by this action.

Absence of the outer piece of an escutcheon, which is used to cover a clearance hole, can delay sprinkler operation in a fire situation.

Sprinklers which are found to be leaking or exhibiting visible signs of corrosion must be replaced.

Automatic sprinklers must never be painted, plated, coated, or otherwise altered after leaving the factory. Modified sprinklers must be replaced. Sprinklers that have been exposed to corrosive products of combustion, but have not operated, should be replaced if they cannot be completely cleaned by wiping the sprinkler with a cloth or by brushing it with a soft bristle brush.

Care must be taken to avoid damage to the sprinklers before, during, and after installation. Sprinklers damaged by dropping, striking, wrench twist/slippage, or the like, must be replaced. Also, replace any sprinkler that has a cracked bulb or that has lost liquid from its bulb. For more information, see Installation section.

The owner is responsible for the inspection, testing, and maintenance of their fire protection system and devices in compliance with this document, as well as with the applicable standards of the National Fire Protection Association such as NFPA 25, in addition to the standards of any other authorities having jurisdiction. Contact the installing contractor or sprinkler manufacturer regarding any questions.

Automatic sprinkler systems are recommended to be inspected, tested, and maintained by a qualified Inspection Service in accordance with local requirements and/or national codes.

Care must be exercised to avoid damage to the sprinklers before, during, and after installation. Sprinklers damaged by dropping, striking, wrench twist/slippage, or the like, must be replaced. Also, replace any sprinkler that has a cracked bulb or that has lost liquid from its bulb. For more information, see Installation section.

Initial and frequent visual inspections of random samples are recommended for corrosion-resistant sprinklers to verify the integrity of the corrosion-resistant material of construction. Thereafter, annual inspections per NFPA 25 should suffice.Inspections of corrosion-resistant sprinklers are recommended at close range, instead of from the floor level per NFPA. Inspection at close range can better determine the exact sprinkler condition and the long-term integrity of the corrosion-resistant material, which can be affected by the corrosive conditions present.

P/N 57 – XXX – X – XXX

		SIN
330	2.8K UPRIGHT (1/2 in. NPT)	TY1131
331	2.8K PENDENT (1/2 in. NPT)	TY1231
340	4.2K UPRIGHT (1/2 in. NPT)	TY2131
341	4.2K PENDENT (1/2 in. NPT)	TY2231
370	5.6K UPRIGHT (1/2 in. NPT)	TY3131
371	5.6K PENDENT (1/2 in. NPT)	TY3231
390	8.0K UPRIGHT (3/4 in. NPT)	TY4131
391	8.0K PENDENT (3/4 in. NPT)	TY4231
360	8.0K UPRIGHT (1/2 in. NPT)	TY4831
361	8.0K PENDENT (1/2 in. NPT)	TY4931

	SPRINKLER FINISH
1	NATURAL BRASS
2	POLY-STAINLESS GREY ALUMINUM (RAL9007)[1] POLYESTER
3	PURE WHITE POLYESTER (RAL9010)[2]
4	SIGNAL WHITE POLYESTER (RAL9003)
5	JET BLACK POLYESTER (RAL9005)[3]
7	LEAD COATED
9	CHROME PLATED

	TEMPERATURE RATINGS
135	135°F (57°C)
155	155°F (68°C)
175	175°F (79°C)
200	200°F (93°C)
286	286°F (141°C)

NOTES
1. Available only on TY3131, TY3231, TY4131, and TY4231
2. Eastern Hemisphere sales only.
3. Available in only 2.8K, 4.2K, and 8.0K, 155°F (68°C) and 200°F (93°C); requires longer lead time to manufacture.

TABLE F
SERIES TY-FRB PENDENT AND UPRIGHT SPRINKLERS
PART NUMBER SELECTION

Limited Warranty

For warranty terms and conditions, visit www.tyco-fire.com.

Ordering Procedure

Contact your local distributor for availability. When placing an order, indicate the full product name and Part Number (P/N).

Sprinkler Assemblies with NPT Thread Connections
Specify: Series TY-FRB (Specify SIN), (specify K-factor), (specify Pendent or Upright) Sprinkler (specify) temperature rating, (specify) finish or coating, P/N (specify from Table F)

Recessed Escutcheon
Specify: Style (10, 20, 30, or 40) Recessed Escutcheon with (specify*) finish, P/N (specify*)

* Refer to Technical Data Sheet TFP770

Sprinkler Wrench
Specify: W-Type 6 Sprinkler Wrench, P/N 56-000-6-387

Specify: W-Type 7 Sprinkler Wrench, P/N 56-850-4-001

1400 Pennbrook Parkway, Lansdale, PA 19446 | Telephone +1-215-362-0700

Johnson Controls

tyco®

Worldwide Contacts | www.tyco-fire.com

Series ELO-231FRB – 11.2 K-factor Upright and Pendent Sprinklers Quick Response, Standard Coverage

General Description

TYCO Series ELO-231FRB 11.2K Quick Response, Standard Coverage, Upright and Pendent Sprinklers (Ref. Figure 1) are automatic sprinklers of the frangible bulb type. They are quick response spray sprinklers that produce a hemispherical water distribution pattern below the deflector.

The 11.2K ELO-231FRB Upright and Pendent Sprinklers were subjected to full scale, high-piled storage fire tests to qualify their use in lieu of 5.6 or 8.0 K-factor standard spray sprinklers for the protection of high-piled storage.

Higher flow rates can be achieved at much lower pressures with the 11.2K ELO-231FRB Sprinklers, making their use highly advantageous in high density applications, such as the protection of high-piled storage.

For in-rack applications, an upright intermediate level version of the Series ELO-231FRB Sprinklers can be obtained by utilizing the Series ELO-231FRB Upright Sprinkler with the WSG-2 Guard & Shield, and a pendent intermediate level version of the Series ELO-231FRB Sprinklers can be obtained by utilizing the Series ELO-231FRB Pendent Sprinkler with the WS-2 Shield. If there is a possibility of the pendent intermediate level version being exposed to mechanical damage, a G-2 Guard can be added.

IMPORTANT

Refer to Technical Data Sheet TFP2300 for warnings pertaining to regulatory and health information.

Always refer to Technical Data Sheet TFP700 for the "INSTALLER WARNING" that provides cautions with respect to handling and installation of sprinkler systems and components. Improper handling and installation can permanently damage a sprinkler system or its components and cause the sprinkler to fail to operate in a fire situation or cause it to operate prematurely.

NOTICE

The Series ELO-231FRB Sprinklers described herein must be installed and maintained in compliance with this document, as well as with the applicable standards of the National Fire Protection Association (NFPA), in addition to the standards of any other authorities having jurisdiction. Failure to do so may impair the performance of these devices.

The owner is responsible for maintaining their fire protection system and devices in proper operating condition. Contact the installing contractor or product manufacturer with any questions.

Installation of Series ELO-231FRB Pendent Sprinklers in recessed escutcheons will void all sprinkler warranties, as well as possibly void the sprinkler's Approvals and/or Listings.

NFPA 13 prohibits the installation of 1/2 in. NPT sprinklers with a K-factor greater than 5.6K in new installations. They are intended for use in retrofit applications only.

Sprinkler Identification Numbers (SINs)

Refer to Table A for sprinkler identification numbers.

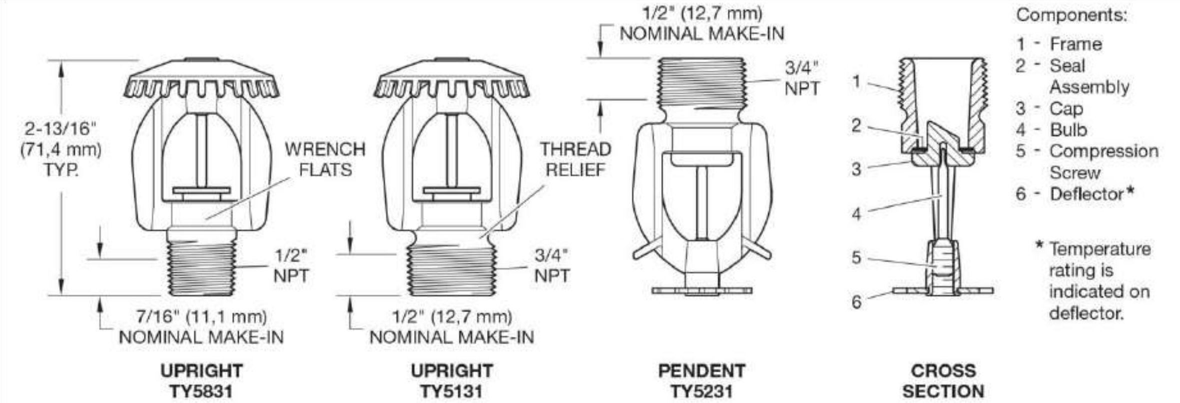


FIGURE 1
SERIES ELO-231FRB 11.2K UPRIGHT - 3/4 IN. NPT (TY5131), UPRIGHT - 1/2 IN. NPT (TY5831), AND PENDENT - 3/4 IN. NPT (TY5231) SPRINKLERS

Technical Data

Approvals
UL and C-UL Listed
FM Approved
NYC Approved
VdS Approved
LPCB Approved

Refer to Table A for complete approval information.

UL and C-UL Listings and FM Approval apply to the service conditions described in the Design Criteria section.

Finishes
Sprinkler: Refer to Table C

Physical Characteristics
Frame . . . . Bronze
Cap . . . . Bronze
Sealing Assembly . . Beryllium Nickel w/TEFLON
Bulb (3mm dia.) . . . . Glass
Compression Screw . . . . Bronze
Deflector . . . . Bronze

Additional Technical Data
Refer to Table A for additional technical data.

Item	Description
Sprinkler Identification Number (SIN)	TY5131 – Upright 3/4 in. NPT TY5231 – Pendent 3/4 in. NPT TY5831 - Upright 1/2 in. NPT TY5131 is a re-designation for Central SIN C5131. TY5231 is a re-designation for Central SIN C5231, G1870, and S2551.
K-factor, (gpm/psi) (lpm/bar)	K=11.2 GPM/psi$^{1/2}$ (161,4 LPM/bar$^{1/2}$)
Temperature Rating °F (°C)[1]	155°F (68°C)[1] 200°F (93°C) 286°F (141°C)
Thread Size	3/4 in. NPT or 1/2 in. NPT
Sprinkler Orientation	Upright/Pendent
Maximum Working Pressure, psi (bar)	175 psi (12,1 bar)

Notes:
1. Refer to Table C for laboratory listings and approvals.

TABLE A
SERIES ELO-231FRB 11.2K UPRIGHT AND PENDENT SPRINKLERS TECHNICAL DATA

Operation

The glass bulb contains a fluid that expands when exposed to heat. When the rated temperature is reached, the fluid expands sufficiently to shatter the glass bulb, allowing the sprinkler to activate and water to flow.

Design Criteria

UL and C-UL Listings Requirements
The 11.2K Model ELO-231FRB (TY5131, TY5231, and TY5831) Sprinklers are to be installed in accordance with NFPA 13 standard sprinkler position and area/density flow calculation requirements for light or ordinary occupancies, as well as high-piled storage occupancies (solid-piled, palletized, rack storage, bin box, and shelf storage including but not limited to Class I-IV and Group A plastics) with a minimum residual (flowing) pressure of 7 psi (0,5 bar) for wet pipe systems only. Refer to Table B for additional information

FM Approval Requirements
The 11.2K Model ELO-231FRB (TY5131 & TY5231) Sprinklers are to be installed in accordance with the applicable control mode density/area guidelines provided by FM Approvals for wet systems only.

Note: *FM Approvals guidelines may differ from UL and C-UL Listings criteria.*

Storage Type	NFPA	FM Global
Sprinkler Type	Standard Coverage	Storage
Response Type	QR	QR
System Type	Wet	Wet
Temperature Rating °F (°C)[1]	155°F (68°C)[1] 200°F (93°C) 286°F (141°C)	155°F (68°C)[1] 200°F (93°C) 286°F (141°C)
Open Frame (i.e., no solid shelves) Single, Double, Multiple-Row, or Portable Rack Storage of Class I-IV and Group A or B Plastics	Refer to NFPA 13	Refer to FM 2-0 and 8-9
Solid Pile or Palletized Storage of Class I-IV and Group A or B Plastics	Refer to NFPA 13	Refer to FM 2-0 and 8-9
Idle Pallet Storage	Refer to NFPA 13	Refer to FM 2-0, 8-9, and 8-24
Rubber Tire Storage	Refer to NFPA 13	Refer to FM 2-0 and 8-3
Roll Paper Storage (Refer to the Standard)	Refer to NFPA 13	Refer to FM 8-21
Flammable/Ignitable Liquid Storage (Refer to the Standard)	Refer to NFPA 30	Refer to FM 7-29
Aerosol Storage (Refer to the Standard)	Refer to NFPA 30B	Refer to FM 7-31
Automotive Components in Portable Racks (Control mode only; refer to the Standard)	Refer to NFPA 13	N/A

Notes:
1. Refer to Table C for laboratory listings and approvals.
N/A – Not Applicable

TABLE B
SERIES ELO-231FRB 11.2K UPRIGHT AND PENDENT SPRINKLERS
COMMODITY SELECTION AND DESIGN CRITERIA OVERVIEW

SPRINKLER TYPE	TEMPERATURE RATING	BULB LIQUID COLOR	SPRINKLER FINISH	
			NATURAL BRASS	CHROME PLATED
UPRIGHT (TY5131) & PENDENT (TY5231)	155°F (68°C)	Red	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6
	200°F (93°C)	Green		
	286°F (141°C)	Blue		
UPRIGHT (TY5831)	155°F (68°C)	Red	1	N/A
	200°F (93°C)	Green		

Notes:
1. UL Listed
2. C-UL Listed
3. FM Approved
4. NYC Approved under MEA 291-04-E
5. VdS Approved, TY5131 Ref. No. G410022 and TY5231 Ref. No. G410023
6. LPCB Approved, TY5131 Ref. No. 094c/01 and TY5231 Ref. No. 094c/02
N/A - Not Available

TABLE C
SERIES ELO-231FRB UPRIGHT AND PENDENT 11.2K SPRINKLERS, QUICK RESPONSE
LABORATORY LISTINGS AND APPROVALS
(Refer to the Design Criteria Section)

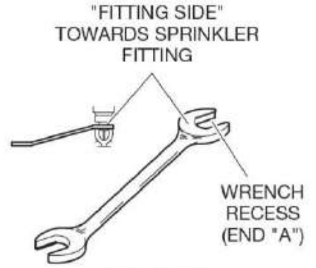


FIGURE 2
W-TYPE 3
SPRINKLER WRENCH

Installation

TYCO Series ELO-231FRB 11.2K Quick Response, Standard Coverage, Upright and Pendent Sprinklers must be installed in accordance with this section.

General Instructions

NOTICE

Do not install any bulb-type sprinkler if the bulb is cracked or there is a loss of liquid from the bulb. With the sprinkler held horizontally, a small air bubble should be present. The diameter of the air bubble is approximately 1/16 in. (1,6 mm) for the 155°F (68°C) to 3/32 in. (2,4 mm) for the 286°F (141°C) temperature ratings.

A leak tight 1/2 in. NPT sprinkler joint should be obtained by applying a minimum-to-maximum torque of 7 to 14 lb-ft (9,5 to 19,0 N·m). A leak-tight 3/4 in. NPT sprinkler joint should be obtained by applying a minimum-to-maximum torque of 10 to 20 lb-ft (13,4 to 26,8 N·m). Higher levels of torque can distort the sprinkler inlet with consequent leakage or impairment of the sprinkler.

Do not attempt to make up for insufficient adjustment in the escutcheon plate by under- or over-tightening the sprinkler. Readjust the position of the sprinkler fitting to suit.

The Series ELO-231FRB Upright and Pendent Sprinklers must be installed in accordance with the following instructions:

Step 1. Upright sprinklers are to be installed in the upright position; pendent sprinklers are to be installed in the pendent position.

Step 2. With pipe thread sealant applied to the pipe threads, hand-tighten the sprinkler into the sprinkler fitting.

Step 3. Tighten the sprinkler into the sprinkler fitting using only the W-Type 3 Sprinkler Wrench (Ref. Figure 2). With reference to Figure 1, the W-Type 3 Sprinkler Wrench is to be applied to the wrench flats.

Care and Maintenance

TYCO Series ELO-231FRB 11.2K Quick Response, Standard Coverage, Upright and Pendent Sprinklers must be maintained and serviced in accordance with this section.

Before closing a fire protection system control valve for maintenance work on the fire protection system that it controls, permission to shut down the affected fire protection system must be obtained from the proper authorities and all personnel who may be affected by this action must be notified.

Sprinklers that are found to be leaking or exhibiting visible signs of corrosion must be replaced.

Automatic sprinklers must never be painted, plated, coated or otherwise altered after leaving the factory. Modified sprinklers must be replaced. Sprinklers that have been exposed to corrosive products of combustion, but have not operated, should be replaced if they cannot be completely cleaned by wiping the sprinkler with a cloth or by brushing it with a soft bristle brush.

Care must be exercised to avoid damage to the sprinklers before, during, and after installation. Sprinklers damaged by dropping, striking, wrench twist/slippage, or the like, must be replaced. Also, replace any sprinkler that has a cracked bulb or that has lost liquid from its bulb. For additional information, refer to the Installation section.

The owner is responsible for the inspection, testing, and maintenance of their fire protection system and devices in compliance with this document, as well as with the applicable standards of the National Fire Protection Association (e.g., NFPA 25), in addition to the standards of any other authorities having jurisdiction. Contact the installing contractor or product manufacturer with any questions.

It is recommended that automatic sprinkler systems be inspected, tested, and maintained by a qualified Inspection Service in accordance with local requirements and/or national codes.

P/N 50 — XXX — X — XXX

		SIN
500	11.2K UPRIGHT (3/4 in. NPT)	TY5131
502	11.2K PENDENT (3/4 in. NPT)	TY5231
503	11.2K UPRIGHT (1/2 in. NPT)	TY5831[b]

	SPRINKLER FINISH
1	NATURAL BRASS
9	CHROME PLATED[a]

	TEMPERATURE RATING
155	155°F (68°C)
200	200°F (93°C)
286	286°F (141°C)[a]

a. For TY5131 and TY5231 sprinklers only.
b. For retrofit applications only.

TABLE D
SERIES ELO-231FRB UPRIGHT & PENDENT 11.2K SPRINKLERS, QUICK RESPONSE PART NUMBER SELECTION

Limited Warranty

For warranty terms and conditions, visit www.tyco-fire.com.

Ordering Procedure

Contact your local distributor for availability. When placing an order, indicate the full product name and Part Number (P/N).

Sprinkler
Specify: Series ELO-231FRB 11.2K Quick Response (specify Pendent or Upright) Sprinkler, (specify SIN), (specify) temperature rating, (specify) finish, P/N (specify from Table D)

Sprinkler Wrench
Specify: W-Type 3 Sprinkler Wrench, P/N 56-895-1-001

Appendix-11: Structural Fire Protection Catalog

FIREPROOFING PRODUCTS

gcp applied technologies

MONOKOTE® MK-6®/HY® and MK-6s

Product data and application instructions

Product Description

Monokote® MK-6®/HY® and MK-6s are single component, spray applied, mill-mixed fire resistive plasters. MK-6/HY and MK-6s have approval for use on structural steel members and fluted decking to provide up to four hours of fire protection, and on flat plate cellular decking for up to three hours with Spatterkote® SK-3.

Note: Monokote MK-6/HY and MK-6s afford the same level of the fire protection at identical protection thicknesses. By simply specifying "Monokote MK-6" the fireproofing subcontractor can select the product that will provide the most efficient fire protection for the specific project conditions.

Features & Benefits

Monokote cementitious fireproofing offers many significant advantages to the architect, owner, applicator and building occupant. These include:

- Proven in-place performance
- Low in-place cost
- Fast, efficient application
- UL fire tested and factory inspected
- Building Code compliant

Delivery & Storage

a. All material to be used for fireproofing shall be delivered in original unopened packages bearing the name of the manufacturer, the brand and proper UL labels for fire hazard and fire resistance classifications.

b. The material shall be kept dry until ready for use. Packages of material shall be kept off the ground, under cover and away from sweating walls and other damp surfaces. All bags that have been exposed to water before use shall be discarded. Stock of material is to be rotated and used before its expiration date.

Steel & Concrete Surfaces

a. Prior to the application of Monokote MK-6, an inspection shall be made to determine that all steel surfaces are acceptable to receive fireproofing. The steel shall be free of oil, grease, rolling compounds or lubricants, loose mill scale, excess rust, noncompatible primer, lock down agent or any other substance that will impair proper adhesion. Where necessary, the cleaning of steel surfaces to receive fireproofing shall be the responsibility of the general contractor.

b. The project architect shall determine if the painted/primed structural steel to receive fireproofing has been tested in accordance with ASTM E119, to provide the required fire resistance rating.

c. Many Fire Resistance Designs allow the use of painted metal floor or roof-deck in place of galvanized decking. Painted decking must be UL listed in the specific fire resistance designs and must carry the UL classification marking. Consult your local GCP sales representative for details.

d. Prior to application of Monokote MK-6, a bonding agent, approved by the fireproofing manufacturer, shall be applied to all concrete substrates to receive MK-6.

e. Fireproofing to the underside of roof deck assemblies shall be done only after roofing application is complete and roof traffic has ceased.

f. No fireproofing shall be applied prior to completion of concrete work on steel decking.

Performance Characteristics

Physical Properties	Recommended Specification	Laboratory Tested* Values	Test Method
Dry density, minimum average	15 pcf (240 kg/m³)	15 pcf (240 kg/m³)	ASTM E605
Bond strength	200 psf (9.6 KPa)	352 psf (16.9 KPa)	ASTM E736
Compression, 10% deformation	8.3 psi (51 kPa)	32 psi (220 KPa)	ASTM E761
Air erosion	Max 0.000 g/ft² (0.00 g/m²)	0.000 g/ft² (0.00 g/m²)	ASTM E859
High velocity air erosion	No continued erosion after 4 hours	No continued erosion after 4 hours	ASTM E859
Corrosion	Does not contribute to corrosion	Does not contribute to corrosion	ASTM E937
Bond impact	No cracking, spalling or delamination	No cracking, spalling or delamination	ASTM E760
Deflection	No cracking, spalling or delamination	No cracking, spalling or delamination	ASTM E759
Resistance to mold growth	No growth after 28 days	No growth after 28 days	ASTM G21
Surface burning characteristics	Flame spread = 0 Smoke developed = 0	Flame spread = 0 Smoke developed = 0	ASTM E84
Combustibility	Less than 5 MJ/m² total, 20 kw/m² peak heat release	Less than 5 MJ/m² total, 20 kw/m² peak heat release	ASTM E1354
Impact penetration	Max 6 cm³ abraded	3.9 cm³	City of San Francisco
Abrasion resistance	Max 15 cm³ abraded	8.3 cm³	City of San Francisco

*Actual laboratory tested values meet or exceed GCP's recommended value. Test reports are available on request from your GCP sales representative.

g. Other trades shall not install ducts, piping, equipment, or other suspended items until the fireproofing is completed and inspected.

h. Other trades shall install clips, hangers, support sleeves, and other attachments that penetrate the fireproofing, prior to application of the fireproofing.

Mixing

a. Monokote Fireproofing shall be mixed by machine in a conventional, plaster-type mixer or a continuous mixer specifically modified for cementitious fireproofing. The mixer shall be kept clean and free of all previously mixed material. The mixer speed in a conventional mixer shall be adjusted to the lowest speed which gives adequate blending of the material and a mixer density of 40–45 pcf (640–720 kg/m^3) of material.

b. Using a suitable metering device and a conventional mixer, all water shall be first added to the mixer as the blades turn. Mixing shall continue until the mix is lump-free, with a creamy texture. All material is to be thoroughly wet. Target density of 43 ± 1 pcf (688 ± 16 kg/m^3) is most desirable. Overmixing Monokote will reduce pumping rate.

Application

a. Application of Monokote Fireproofing can be made in the following sequence:
   1. For thicknesses of approximately ½ in. (13 mm) or less, apply in one pass.
   2. For thicknesses of ⅝ in. (16 mm) or greater, apply subsequent passes after the first coat has set.

b. Spatterkote SK-3 shall be applied to all cellular steel floor units with flat plate on the bottom and to roof decking where required prior to application of Monokote. Spatterkote shall be applied in accordance with manufacturer's application instructions.

c. Monokote Fireproofing material shall not be used if it contains partially set, frozen or caked material.

d. The minimum average density shall be that required by the manufacturer, listed in the UL Fire Resistance Directory for each rating indicated, ICBO Evaluation Report, as required by the authority having jurisdiction, or minimum average 15 lbs/ft^3 (240 kg/m^3), whichever is greater.

e. Monokote shall be mixed with water at the job site.

f. Monokote Accelerator is to be used with Monokote Fireproofing* to enhance set character-istics and product yield. The Monokote Accelerator is injected into the Monokote Fire-proofing at the spray gun. Monokote Accelerator shall be mixed and used according to manufactur-ers recommendations.

g. Monokote is applied directly to the steel, at various rates of application which will be job dependent, using standard plastering type equipment or continuous mixer/pump units. A spray gun, with a properly sized orifice and spray shield and air pressure at the nozzle of approximately 20 psi (38 KPa), will provide the correct hangability, density and appearance. NOTE: If freshly sprayed Monokote does not adhere properly, it is probably due to a too wet mix, poor thickness control, or an improperly cleaned substrate.

Temperature & Ventilation

a. An air and substrate temperature of 40°F (4.4°C) minimum shall be maintained for 24 hours prior to application, during application and for a minimum of 24 hours after application of Monokote.

b. Provisions shall be made for ventilation to properly dry the fireproofing after application. In enclosed areas lacking natural ventilation, air circulation and ventilation must be provided to achieve a minimum total fresh air exchange rate of 4 times per hour until the material is substantially dry.

Field Tests

a. The architect will select an independent testing laboratory (for which the owner will pay) to sample and verify the thickness and density of the fireproofing in accordance with the the applicable building code.

b. The architect will select an independent testing laboratory (for which the owner will pay) to randomly sample and verify the bond strength of the fireproofing in accordance with the provisions of ASTM E736.

c. Results of the above tests will be made available to all parties at the completion of pre-designated areas which shall have been determined at a pre-job conference.

Safety

a. Monokote is slippery when wet. The general contractor and applicator shall be responsible for posting appropriate cautionary "SLIPPERY WHEN WET" signs. Signs should be posted in all areas in contact with wet fireproofing material. Anti-slip surfaces should be used on all working surfaces.

b. Material Safety Data Sheets for Monokote MK-6/HY and MK-6s are available on our web site at www.gcpat.com or by calling
866-333-3SBM.

Use of accelerator with MK-6s will provide rapid set but will not result in yield increase.

GCP Applied Technologies Inc., 62 Whittemore Avenue, Cambridge, MA 02140 USA.

In Canada, GCP Canada, Inc., 294 Clements Road, West, Ajax, Ontario, Canada L1S 3C6.

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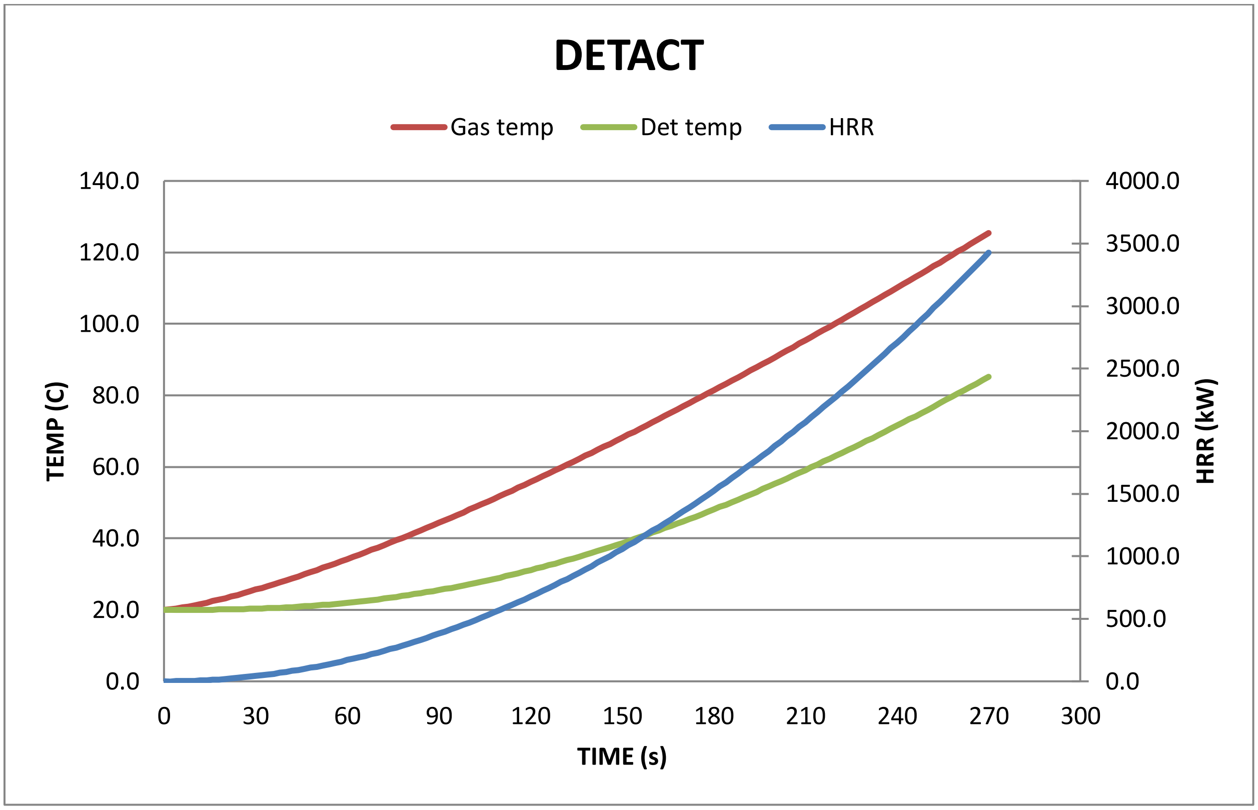
gcp applied technologies

Appendix-11: Detect Model



DETACT.XLS: Estimate of the response time of ceiling mounted fire detectors

INPUT PARAMETERS			CALC. PARAMETERS	
Ceiling height (H)	5	m	R/H	0.646
Radial distance (R)	3.2	m	dT(cj)/dT(pl)	0.401
Ambient temperature (To)	20	C	u(cj)/u(pl)	0.288
Actuation temperature (Td)	68	C	Rep. t2 coeff.	k
Response time index (RTI)	135	(m-s)1/2	Slow	0.003
Fire growth power (n)	2	-	Medium	0.012
Fire growth coefficient (k)	0.047	kW/s^n	Fast	0.047
Time step (dt)	2	s	Ultrafast	0.400

Calculation time (s)	HRR	Gas temp	Gas velocity	Det temp	dT/dt
0	0.0	20.0	0.00	20.00	0.0000
2	0.2	20.2	0.10	20.00	0.0004
4	0.8	20.4	0.15	20.00	0.0011
6	1.7	20.7	0.20	20.00	0.0022
8	3.0	21.0	0.24	20.01	0.0035
10	4.7	21.3	0.28	20.01	0.0051
12	6.8	21.7	0.32	20.02	0.0068
14	9.2	22.0	0.35	20.04	0.0088
16	12.0	22.4	0.39	20.06	0.0109
18	15.2	22.8	0.42	20.08	0.0133
20	18.8	23.3	0.45	20.10	0.0157
22	22.7	23.7	0.48	20.14	0.0184
24	27.1	24.2	0.51	20.17	0.0211
26	31.8	24.7	0.53	20.21	0.0240
28	36.8	25.1	0.56	20.26	0.0270
30	42.3	25.6	0.59	20.32	0.0301
32	48.1	26.1	0.61	20.38	0.0334
34	54.3	26.7	0.64	20.44	0.0367
36	60.9	27.2	0.66	20.52	0.0402
38	67.9	27.7	0.69	20.60	0.0437
40	75.2	28.3	0.71	20.68	0.0473
42	82.9	28.8	0.73	20.78	0.0510
44	91.0	29.4	0.76	20.88	0.0548
46	99.5	30.0	0.78	20.99	0.0586
48	108.3	30.5	0.80	21.11	0.0625
50	117.5	31.1	0.82	21.23	0.0665
52	127.1	31.7	0.85	21.37	0.0706
54	137.1	32.3	0.87	21.51	0.0747
56	147.4	32.9	0.89	21.66	0.0788
58	158.1	33.6	0.91	21.81	0.0830
60	169.2	34.2	0.93	21.98	0.0872
62	180.7	34.8	0.95	22.15	0.0915
64	192.5	35.5	0.97	22.34	0.0958
66	204.7	36.1	0.99	22.53	0.1002
68	217.3	36.8	1.01	22.73	0.1046
70	230.3	37.4	1.03	22.94	0.1090
72	243.6	38.1	1.05	23.16	0.1134
74	257.4	38.8	1.07	23.38	0.1179
76	271.5	39.4	1.09	23.62	0.1224
78	285.9	40.1	1.11	23.86	0.1269
80	300.8	40.8	1.13	24.12	0.1314
82	316.0	41.5	1.15	24.38	0.1359
84	331.6	42.2	1.16	24.65	0.1404
86	347.6	42.9	1.18	24.93	0.1450
88	364.0	43.6	1.20	25.22	0.1495
90	380.7	44.4	1.22	25.52	0.1541
92	397.8	45.1	1.24	25.83	0.1587
94	415.3	45.8	1.26	26.15	0.1632
96	433.2	46.6	1.27	26.47	0.1678
98	451.4	47.3	1.29	26.81	0.1724
100	470.0	48.0	1.31	27.15	0.1769
102	489.0	48.8	1.33	27.51	0.1815
104	508.4	49.5	1.34	27.87	0.1860
106	528.1	50.3	1.36	28.24	0.1906
108	548.2	51.1	1.38	28.62	0.1951
110	568.7	51.8	1.39	29.01	0.1996
112	589.6	52.6	1.41	29.41	0.2041
114	610.8	53.4	1.43	29.82	0.2086
116	632.4	54.2	1.44	30.24	0.2131
118	654.4	55.0	1.46	30.67	0.2175
120	676.8	55.8	1.48	31.10	0.2219
122	699.5	56.6	1.49	31.54	0.2264
124	722.7	57.4	1.51	32.00	0.2308
126	746.2	58.2	1.53	32.46	0.2351
128	770.0	59.0	1.54	32.93	0.2395
130	794.3	59.8	1.56	33.41	0.2438
132	818.9	60.6	1.57	33.90	0.2482
134	843.9	61.4	1.59	34.39	0.2525
136	869.3	62.2	1.61	34.90	0.2567
138	895.1	63.1	1.62	35.41	0.2610
140	921.2	63.9	1.64	35.93	0.2652
142	947.7	64.8	1.65	36.46	0.2694
144	974.6	65.6	1.67	37.00	0.2735
146	1001.9	66.4	1.68	37.55	0.2777
148	1029.5	67.3	1.70	38.10	0.2818
150	1057.5	68.1	1.71	38.67	0.2859
152	1085.9	69.0	1.73	39.24	0.2899
154	1114.7	69.9	1.74	39.82	0.2939
156	1143.8	70.7	1.76	40.41	0.2979
158	1173.3	71.6	1.77	41.00	0.3019
160	1203.2	72.5	1.79	41.61	0.3058
162	1233.5	73.3	1.80	42.22	0.3097
164	1264.1	74.2	1.82	42.84	0.3136
166	1295.1	75.1	1.83	43.46	0.3174
168	1326.5	76.0	1.85	44.10	0.3212
170	1358.3	76.9	1.86	44.74	0.3250
172	1390.4	77.8	1.88	45.39	0.3288
174	1423.0	78.7	1.89	46.05	0.3325
176	1455.9	79.6	1.91	46.71	0.3362
178	1489.1	80.5	1.92	47.39	0.3398
180	1522.8	81.4	1.94	48.07	0.3434
182	1556.8	82.3	1.95	48.75	0.3470
184	1591.2	83.2	1.96	49.45	0.3506
186	1626.0	84.1	1.98	50.15	0.3541
188	1661.2	85.1	1.99	50.86	0.3576
190	1696.7	86.0	2.01	51.57	0.3611
192	1732.6	86.9	2.02	52.29	0.3645
194	1768.9	87.8	2.03	53.02	0.3679
196	1805.6	88.8	2.05	53.76	0.3712
198	1842.6	89.7	2.06	54.50	0.3746
200	1880.0	90.7	2.08	55.25	0.3779
202	1917.8	91.6	2.09	56.01	0.3811
204	1956.0	92.5	2.10	56.77	0.3844
206	1994.5	93.5	2.12	57.54	0.3876
208	2033.4	94.4	2.13	58.31	0.3907
210	2072.7	95.4	2.14	59.09	0.3939
212	2112.4	96.4	2.16	59.88	0.3970
214	2152.4	97.3	2.17	60.68	0.4001
216	2192.8	98.3	2.19	61.48	0.4031
218	2233.6	99.3	2.20	62.28	0.4061
220	2274.8	100.2	2.21	63.09	0.4091
222	2316.3	101.2	2.23	63.91	0.4121
224	2358.3	102.2	2.24	64.74	0.4150
226	2400.6	103.2	2.25	65.57	0.4179
228	2443.2	104.1	2.27	66.40	0.4208
230	2486.3	105.1	2.28	67.24	0.4236
232	2529.7	106.1	2.29	68.09	0.4264
234	2573.5	107.1	2.31	68.94	0.4292
236	2617.7	108.1	2.32	69.80	0.4319
238	2662.3	109.1	2.33	70.67	0.4347
240	2707.2	110.1	2.34	71.54	0.4374
242	2752.5	111.1	2.36	72.41	0.4400
244	2798.2	112.1	2.37	73.29	0.4427
246	2844.3	113.1	2.38	74.18	0.4453
248	2890.7	114.1	2.40	75.07	0.4478
250	2937.5	115.1	2.41	75.96	0.4504
252	2984.7	116.2	2.42	76.86	0.4529
254	3032.3	117.2	2.43	77.77	0.4554
256	3080.2	118.2	2.45	78.68	0.4579
258	3128.5	119.2	2.46	79.60	0.4604
260	3177.2	120.2	2.47	80.52	0.4628
262	3226.3	121.3	2.49	81.44	0.4652
264	3275.7	122.3	2.50	82.37	0.4675
266	3325.5	123.3	2.51	83.31	0.4699
268	3375.7	124.4	2.52	84.25	0.4722
270	3426.3	125.4	2.54	85.19	0.4745

Appendix-12: Structural Fire Protection Assessment

Standard Time Temperature Curve

Temperature @ T_0 =	20	°C
Seconds	0	20.00
↘	10	164.96
	20	217.51
	30	255.18
	40	285.26
	50	310.57
1 Min.	60	332.53
2 Min.	120	426.04
5 Min.	300	568.46
10 Min.	600	680.31
30 Min.	1800	839.27
1 Hour	3600	923.56
2 Hour	7200	1007.50
3 Hour	10800	1064.11
4 Hour	14400	1110.44
5 Hour	18000	1150.89
6 Hour	21600	1187.35
7 Hour	25200	1220.83
8 Hour	28800	1251.98
9 Hour	32400	1281.22
10 Hour	36000	1308.88

$$T = 750[1 - e^{-3.79553\sqrt{t_h}}] + 170.41\sqrt{t_h} + T_0$$

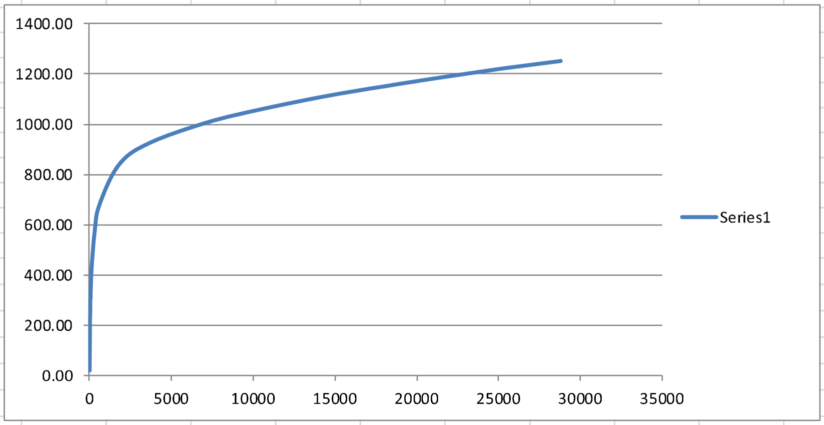


Figure: Standard time temperature curve

Unprotected Column

Output
Input

ε =	0.7				
c_s =	600.00	J/Kg·K			
σ =	5.67E-08	W/(m²·K⁴)			
ρ =	7.86E+03	Kg/m³			
W/D =	2.28	lbs/ft·in =	133.5832	Kg/m²	
Δt =	10.00	Seconds			

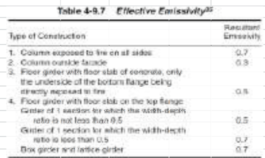


Table 4-9.7 *Effective Emissivity*[35]

Type of Construction	Resultant Emissivity
1. Column exposed to fire on all sides	0.7
2. Column outside facade	0.3
3. Floor girder with floor slab of concrete, only the underside of the bottom flange being directly exposed to fire	0.5
4. Floor girder with floor slab on the top flange	
Girder of I section for which the width-depth ratio is not less than 0.5	0.5
Girder of I section for which the width-depth ratio is less than 0.5	0.7
Box girder and lattice girder	0.7

$$h_t = \frac{\varepsilon\sigma}{T_f - T_s}\left(T_f^4 - T_s^4\right) + 25$$

Seconds	Time	T_s (°C)	T_f (°C)	T_f-T_s (°C)	h_t	ΔT_s (°C)	
↘	0	20	20.00	0.00	25	0	
	10	20.00	164.96	144.96	33.0703	0.598109	
	20	20.60	217.51	196.91	35.1882	0.864486	
	30	21.46	255.18	233.72	36.96	1.077744	
	40	22.54	285.26	262.72	38.5436	1.263426	
1 Min.	50	23.80	310.57	286.77	40.0021	1.431238	
	60	25.24	332.53	307.30	41.3689	1.586086	
	70	26.82	351.98	325.16	42.6643	1.730857	
	80	28.55	369.48	340.92	43.9022	1.867415	
	90	30.42	385.39	354.97	45.0924	1.997052	
	100	32.42	399.99	367.57	46.2423	2.120706	
	110	34.54	413.49	378.95	47.3576	2.239089	
	120	36.78	426.04	389.27	48.4429	2.352751	
	130	39.13	437.78	398.65	49.5021	2.462138	
	140	41.59	448.79	407.20	50.5383	2.567608	
	150	44.16	459.17	415.02	51.5541	2.669464	
	160	46.83	468.99	422.16	52.5519	2.767958	
	170	49.60	478.29	428.69	53.5336	2.863307	
	180	52.46	487.13	434.67	54.501	2.955698	
	190	55.42	495.55	440.14	55.4556	3.045296	
	200	58.46	503.59	445.13	56.3988	3.132244	
	210	61.59	511.28	449.69	57.3319	3.21667	
	220	64.81	518.65	453.84	58.2559	3.298688	
	230	68.11	525.72	457.61	59.1719	3.378402	
	240	71.49	532.52	461.03	60.0807	3.455903	
	250	74.94	539.06	464.11	60.9833	3.531276	
	260	78.47	545.35	466.88	61.8805	3.604598	
	270	82.08	551.43	469.35	62.7728	3.675939	
	280	85.75	557.30	471.54	63.6611	3.745363	
	290	89.50	562.97	473.47	64.5459	3.812929	
5 Min.	300	93.31	568.46	475.15	65.4277	3.878691	
	310	97.19	573.77	476.58	66.3073	3.942702	
	320	101.13	578.92	477.79	67.1849	4.005006	
	330	105.14	583.92	478.78	68.0612	4.065647	
	340	109.20	588.76	479.56	68.9366	4.124667	
	350	113.33	593.47	480.14	69.8114	4.182101	
	360	117.51	598.05	480.54	70.6862	4.237985	
	370	121.75	602.50	480.75	71.5612	4.292352	
	380	126.04	606.83	480.79	72.4368	4.345232	
	390	130.39	611.05	480.66	73.3134	4.396653	
	400	134.78	615.16	480.38	74.1912	4.446642	
	410	139.23	619.17	479.94	75.0706	4.495223	
	420	143.73	623.07	479.35	75.9519	4.542419	
	430	148.27	626.89	478.62	76.8353	4.588251	
	440	152.86	630.61	477.75	77.7211	4.632741	
	450	157.49	634.24	476.75	78.6095	4.675906	
	460	162.16	637.79	475.63	79.5009	4.717764	
	470	166.88	641.26	474.38	80.3953	4.758331	
	480	171.64	644.66	473.02	81.293	4.797623	
	490	176.44	647.98	471.54	82.1943	4.835654	
	500	181.27	651.22	469.95	83.0993	4.872436	
	510	186.15	654.40	468.26	84.0081	4.907983	
	520	191.05	657.52	466.46	84.921	4.942305	
	530	196.00	660.57	464.57	85.8382	4.975413	
	540	200.97	663.56	462.58	86.7597	5.007316	
	550	205.98	666.48	460.51	87.6857	5.038025	
	560	211.02	669.36	458.34	88.6164	5.067546	
	570	216.09	672.17	456.09	89.5519	5.095889	
	580	221.18	674.94	453.75	90.4923	5.12306	
	590	226.30	677.65	451.34	91.4378	5.149066	
10 Min.	600	231.45	680.31	448.85	92.3883	5.173912	
	610	236.63	682.92	446.29	93.3441	5.197605	
	620	241.82	685.48	443.66	94.3053	5.22015	
	630	247.04	688.00	440.96	95.2718	5.241551	
	640	252.29	690.48	438.19	96.2438	5.261813	
	650	257.55	692.91	435.36	97.2213	5.280939	
	660	262.83	695.30	432.47	98.2045	5.298935	
	670	268.13	697.65	429.53	99.1933	5.315803	
	680	273.44	699.97	426.52	100.188	5.331546	
	690	278.78	702.24	423.46	101.188	5.346168	
	700	284.12	704.48	420.35	102.194	5.359671	
	710	289.48	706.68	417.20	103.206	5.372058	
	720	294.85	708.84	413.99	104.224	5.383332	
	730	300.24	710.97	410.74	105.247	5.393495	
	740	305.63	713.07	407.44	106.276	5.402551	
	750	311.03	715.14	404.11	107.311	5.4105	
	760	316.44	717.17	400.73	108.352	5.417347	
	770	321.86	719.18	397.32	109.399	5.423093	
	780	327.28	721.15	393.87	110.451	5.427741	
	790	332.71	723.10	390.39	111.509	5.431294	
	800	338.14	725.02	386.87	112.573	5.433754	
	810	343.58	726.91	383.33	113.643	5.435125	
	820	349.01	728.77	379.76	114.718	5.43541	
	830	354.45	730.60	376.16	115.798	5.434613	
	840	359.88	732.42	372.53	116.884	5.432736	
	850	365.31	734.20	368.89	117.975	5.429783	
	860	370.74	735.96	365.22	119.072	5.42576	
	870	376.17	737.70	361.53	120.174	5.42067	
	880	381.59	739.42	357.83	121.281	5.414519	
	890	387.00	741.11	354.10	122.393	5.40731	
	900	392.41	742.78	350.37	123.509	5.399051	
	910	397.81	744.43	346.61	124.631	5.389747	
	920	403.20	746.05	342.85	125.757	5.379404	
	930	408.58	747.66	339.08	126.887	5.368029	
	940	413.95	749.24	335.30	128.022	5.355629	
	950	419.30	750.81	331.51	129.162	5.342212	
	960	424.65	752.36	327.71	130.305	5.327787	
	970	429.97	753.88	323.91	131.452	5.312362	
	980	435.29	755.39	320.11	132.603	5.295946	
	990	440.58	756.88	316.30	133.758	5.278549	
	1000	445.86	758.36	312.49	134.916	5.260181	
	1010	451.12	759.81	308.69	136.077	5.240853	
	1020	456.36	761.25	304.89	137.241	5.220577	
	1030	461.58	762.67	301.09	138.408	5.199364	
	1040	466.78	764.07	297.29	139.578	5.177228	
	1050	471.96	765.46	293.50	140.75	5.15418	
	1060	477.11	766.84	289.72	141.924	5.130235	
	1070	482.24	768.19	285.95	143.101	5.105407	
	1080	487.35	769.54	282.19	144.279	5.079711	
	1090	492.43	770.86	278.44	145.46	5.053161	
	1100	497.48	772.18	274.69	146.641	5.025775	
	1110	502.51	773.48	270.97	147.824	4.997568	
	1120	507.51	774.76	267.25	149.007	4.968557	
	1130	512.47	776.03	263.56	150.192	4.93876	
	1140	517.41	777.29	259.88	151.377	4.908195	
	1150	522.32	778.53	256.21	152.562	4.87688	
	1160	527.20	779.76	252.57	153.747	4.844835	
	1170	532.04	780.98	248.94	154.933	4.812079	
	1180	536.85	782.19	245.33	156.117	4.778632	
	1190	541.63	783.38	241.75	157.301	4.744514	
	1200	546.38	784.56	238.18	158.485	4.709746	
	1210	551.09	785.73	234.64	159.667	4.67435	
	1220	555.76	786.89	231.13	160.848	4.638346	
	1230	560.40	788.04	227.64	162.027	4.601758	
	1240	565.00	789.17	224.17	163.204	4.564607	
	1250	569.57	790.29	220.73	164.38	4.526916	Minutes 50 Seconds

Protected Column

Output

Input

Seconds	Time	T_s (°C)	T_f (°C)	T_f-T_s (°C)	k/h	ΔT_s (°C)
↘	0	20.00	20.00	0.00	3.41	0.00
	10	20.00	164.96	144.96	3.41	0.06
	20	20.06	217.51	197.45	3.41	0.08
	30	20.13	255.18	235.04	3.41	0.09
	40	20.22	285.26	265.04	3.41	0.10
	50	20.33	310.57	290.24	3.41	0.11
	60	20.44	332.53	312.09	3.41	0.12
	70	20.56	351.98	331.42	3.41	0.13
	80	20.69	369.48	348.78	3.41	0.14
	90	20.83	385.39	364.56	3.41	0.14
	100	20.97	399.99	379.02	3.41	0.15
	110	21.12	413.49	392.37	3.41	0.15
	120	21.27	426.04	404.78	3.41	0.16
	130	21.43	437.78	416.35	3.41	0.16
	140	21.59	448.79	427.21	3.41	0.17
	150	21.75	459.17	437.42	3.41	0.17
	160	21.92	468.99	447.06	3.41	0.17
	170	22.10	478.29	456.19	3.41	0.18
	180	22.28	487.13	464.85	3.41	0.18
	190	22.46	495.55	473.10	3.41	0.18
	200	22.64	503.59	480.95	3.41	0.19

W14X228

k_i =	0.116	W/m·K	
c_i =	1825	J/Kg·K	
ρ_i =	240.5	Kg/m^3	
h_i =	1.34	inches =	0.034036
W/D =	2.28	lbs/ft·in =	133.5832
c_s =	600		
Δt =	10		

$$\Delta T_s = \frac{k_i}{h_i}\left[\frac{T_f - T_s}{c_s \frac{W}{D} + \frac{c_i \rho_i h_i}{2}}\right]\Delta t$$

	210	22.83	511.28	488.46	3.41	0.19
	220	23.02	518.65	495.63	3.41	0.19
	230	23.21	525.72	502.51	3.41	0.20
	240	23.41	532.52	509.11	3.41	0.20
	250	23.60	539.06	515.45	3.41	0.20
	260	23.80	545.35	521.55	3.41	0.20
	270	24.01	551.43	527.42	3.41	0.21
	280	24.21	557.30	533.09	3.41	0.21
	290	24.42	562.97	538.55	3.41	0.21
5 Min.	300	24.63	568.46	543.83	3.41	0.21
	310	24.84	573.77	548.93	3.41	0.21
	320	25.05	578.92	553.87	3.41	0.22
	330	25.27	583.92	558.65	3.41	0.22
	340	25.49	588.76	563.28	3.41	0.22
	350	25.71	593.47	567.77	3.41	0.22
	360	25.93	598.05	572.12	3.41	0.22
	370	26.15	602.50	576.35	3.41	0.22
	380	26.37	606.83	580.46	3.41	0.23
	390	26.60	611.05	584.45	3.41	0.23
	400	26.83	615.16	588.33	3.41	0.23
	410	27.06	619.17	592.11	3.41	0.23
	420	27.29	623.07	595.79	3.41	0.23
	430	27.52	626.89	599.37	3.41	0.23
	440	27.75	630.61	602.86	3.41	0.23
	450	27.99	634.24	606.26	3.41	0.24
	460	28.22	637.79	609.57	3.41	0.24
	470	28.46	641.26	612.81	3.41	0.24
	480	28.70	644.66	615.96	3.41	0.24
	490	28.94	647.98	619.04	3.41	0.24
	500	29.18	651.22	622.05	3.41	0.24
	510	29.42	654.40	624.99	3.41	0.24

	520	29.66	657.52	627.86	3.41	0.24
	530	29.91	660.57	630.66	3.41	0.25
	540	30.15	663.56	633.40	3.41	0.25
	550	30.40	666.48	636.09	3.41	0.25
	560	30.65	669.36	638.71	3.41	0.25
	570	30.89	672.17	641.28	3.41	0.25
	580	31.14	674.94	643.79	3.41	0.25
	590	31.39	677.65	646.25	3.41	0.25
10 Min.	600	31.64	680.31	648.66	3.41	0.25
	610	31.90	682.92	651.02	3.41	0.25
	620	32.15	685.48	653.33	3.41	0.25
	630	32.40	688.00	655.60	3.41	0.26
	640	32.66	690.48	657.82	3.41	0.26
	650	32.92	692.91	660.00	3.41	0.26
	660	33.17	695.30	662.13	3.41	0.26
	670	33.43	697.65	664.22	3.41	0.26
	680	33.69	699.97	666.28	3.41	0.26
	690	33.95	702.24	668.29	3.41	0.26
	700	34.21	704.48	670.27	3.41	0.26
	710	34.47	706.68	672.21	3.41	0.26
	720	34.73	708.84	674.11	3.41	0.26
	730	34.99	710.97	675.98	3.41	0.26
	740	35.25	713.07	677.82	3.41	0.26
	750	35.52	715.14	679.62	3.41	0.26
	760	35.78	717.17	681.39	3.41	0.27
	770	36.05	719.18	683.13	3.41	0.27
	780	36.31	721.15	684.84	3.41	0.27
	790	36.58	723.10	686.52	3.41	0.27
	800	36.85	725.02	688.17	3.41	0.27
	810	37.11	726.91	689.79	3.41	0.27
	820	37.38	728.77	691.39	3.41	0.27

	830	37.65	730.60	692.95	3.41	0.27
	840	37.92	732.42	694.49	3.41	0.27
	850	38.19	734.20	696.01	3.41	0.27
	860	38.46	735.96	697.50	3.41	0.27
	870	38.73	737.70	698.97	3.41	0.27
	880	39.01	739.42	700.41	3.41	0.27
	890	39.28	741.11	701.83	3.41	0.27
15 Min.	900	39.55	742.78	703.23	3.41	0.27
	910	39.82	744.43	704.60	3.41	0.27
	920	40.10	746.05	705.95	3.41	0.27
	930	40.37	747.66	707.29	3.41	0.28
	940	40.65	749.24	708.60	3.41	0.28
	950	40.92	750.81	709.89	3.41	0.28
	960	41.20	752.36	711.16	3.41	0.28
	970	41.48	753.88	712.41	3.41	0.28
	980	41.75	755.39	713.64	3.41	0.28
	990	42.03	756.88	714.85	3.41	0.28
	1000	42.31	758.36	716.05	3.41	0.28
	1010	42.59	759.81	717.22	3.41	0.28
	1020	42.87	761.25	718.38	3.41	0.28
	1030	43.15	762.67	719.52	3.41	0.28
	1040	43.43	764.07	720.65	3.41	0.28
	1050	43.71	765.46	721.76	3.41	0.28
	1060	43.99	766.84	722.85	3.41	0.28
	1070	44.27	768.19	723.93	3.41	0.28
	1080	44.55	769.54	724.99	3.41	0.28
	1090	44.83	770.86	726.03	3.41	0.28
	1100	45.11	772.18	727.06	3.41	0.28
	1110	45.40	773.48	728.08	3.41	0.28
	1120	45.68	774.76	729.08	3.41	0.28
	1130	45.96	776.03	730.07	3.41	0.28

	1140	46.25	777.29	731.04	3.41	0.28
	1150	46.53	778.53	732.00	3.41	0.28
	1160	46.82	779.76	732.95	3.41	0.29
	1170	47.10	780.98	733.88	3.41	0.29
	1180	47.39	782.19	734.80	3.41	0.29
	1190	47.67	783.38	735.71	3.41	0.29
20 Min.	1200	47.96	784.56	736.60	3.41	0.29
	1210	48.25	785.73	737.49	3.41	0.29
	1220	48.53	786.89	738.36	3.41	0.29
	1230	48.82	788.04	739.22	3.41	0.29
	1240	49.11	789.17	740.06	3.41	0.29
	1250	49.40	790.29	740.90	3.41	0.29
	1260	49.68	791.41	741.72	3.41	0.29
	1270	49.97	792.51	742.54	3.41	0.29
	1280	50.26	793.60	743.34	3.41	0.29
	1290	50.55	794.68	744.13	3.41	0.29
	1300	50.84	795.75	744.91	3.41	0.29
	1310	51.13	796.82	745.69	3.41	0.29
	1320	51.42	797.87	746.45	3.41	0.29
	1330	51.71	798.91	747.20	3.41	0.29
	1340	52.00	799.94	747.94	3.41	0.29
	1350	52.29	800.96	748.67	3.41	0.29
	1360	52.58	801.98	749.40	3.41	0.29
	1370	52.87	802.98	750.11	3.41	0.29
	1380	53.17	803.98	750.81	3.41	0.29
	1390	53.46	804.96	751.51	3.41	0.29
	1400	53.75	805.94	752.19	3.41	0.29
	1410	54.04	806.91	752.87	3.41	0.29
	1420	54.34	807.87	753.54	3.41	0.29
	1430	54.63	808.83	754.20	3.41	0.29
	1440	54.92	809.77	754.85	3.41	0.29

	1450	55.22	810.71	755.49	3.41	0.29
	1460	55.51	811.64	756.13	3.41	0.29
	1470	55.80	812.56	756.76	3.41	0.29
	1480	56.10	813.47	757.38	3.41	0.29
	1490	56.39	814.38	757.99	3.41	0.29
25 Min.	1500	56.69	815.28	758.59	3.41	0.30
	1510	56.98	816.17	759.19	3.41	0.30
	1520	57.28	817.06	759.78	3.41	0.30
	1530	57.57	817.93	760.36	3.41	0.30
	1540	57.87	818.80	760.93	3.41	0.30
	1550	58.16	819.67	761.50	3.41	0.30
	1560	58.46	820.52	762.06	3.41	0.30
	1570	58.76	821.37	762.62	3.41	0.30
	1580	59.05	822.22	763.16	3.41	0.30
	1590	59.35	823.05	763.70	3.41	0.30
	1600	59.65	823.88	764.24	3.41	0.30
	1610	59.95	824.71	764.76	3.41	0.30
	1620	60.24	825.53	765.28	3.41	0.30
	1630	60.54	826.34	765.80	3.41	0.30
	1640	60.84	827.14	766.30	3.41	0.30
	1650	61.14	827.94	766.81	3.41	0.30
	1660	61.43	828.74	767.30	3.41	0.30
	1670	61.73	829.52	767.79	3.41	0.30
	1680	62.03	830.31	768.27	3.41	0.30
	1690	62.33	831.08	768.75	3.41	0.30
	1700	62.63	831.85	769.22	3.41	0.30
	1710	62.93	832.62	769.69	3.41	0.30
	1720	63.23	833.38	770.15	3.41	0.30
	1730	63.53	834.13	770.61	3.41	0.30
	1740	63.83	834.88	771.06	3.41	0.30
	1750	64.13	835.63	771.50	3.41	0.30

	1760	64.43	836.37	771.94	3.41	0.30
	1770	64.73	837.10	772.37	3.41	0.30
	1780	65.03	837.83	772.80	3.41	0.30
	1790	65.33	838.55	773.23	3.41	0.30
30 Min.	1800	65.63	839.27	773.64	3.41	0.30
	1810	65.93	839.99	774.06	3.41	0.30
	1820	66.23	840.70	774.46	3.41	0.30
	1830	66.53	841.40	774.87	3.41	0.30
	1840	66.83	842.10	775.27	3.41	0.30
	1850	67.14	842.80	775.66	3.41	0.30
	1860	67.44	843.49	776.05	3.41	0.30
	1870	67.74	844.17	776.43	3.41	0.30
	1880	68.04	844.86	776.81	3.41	0.30
	1890	68.34	845.53	777.19	3.41	0.30
	1900	68.65	846.21	777.56	3.41	0.30
	1910	68.95	846.88	777.93	3.41	0.30
	1920	69.25	847.54	778.29	3.41	0.30
	1930	69.55	848.20	778.65	3.41	0.30
	1940	69.86	848.86	779.00	3.41	0.30
	1950	70.16	849.51	779.35	3.41	0.30
	1960	70.46	850.16	779.70	3.41	0.30
	1970	70.77	850.80	780.04	3.41	0.30
	1980	71.07	851.44	780.37	3.41	0.30
	1990	71.37	852.08	780.71	3.41	0.30
	2000	71.68	852.71	781.04	3.41	0.30
	2010	71.98	853.34	781.36	3.41	0.30
	2020	72.28	853.97	781.68	3.41	0.30
	2030	72.59	854.59	782.00	3.41	0.30
	2040	72.89	855.21	782.31	3.41	0.30
	2050	73.20	855.82	782.62	3.41	0.30
	2060	73.50	856.43	782.93	3.41	0.30

	2070	73.81	857.04	783.23	3.41	0.30
	2080	74.11	857.64	783.53	3.41	0.30
	2090	74.42	858.24	783.83	3.41	0.30
35 Min.	2100	74.72	858.84	784.12	3.41	0.31
	2110	75.03	859.43	784.41	3.41	0.31
	2120	75.33	860.02	784.69	3.41	0.31
	2130	75.64	860.61	784.97	3.41	0.31
	2140	75.94	861.19	785.25	3.41	0.31
	2150	76.25	861.77	785.53	3.41	0.31
	2160	76.55	862.35	785.80	3.41	0.31
	2170	76.86	862.92	786.07	3.41	0.31
	2180	77.16	863.49	786.33	3.41	0.31
	2190	77.47	864.06	786.59	3.41	0.31
	2200	77.78	864.63	786.85	3.41	0.31
	2210	78.08	865.19	787.11	3.41	0.31
	2220	78.39	865.75	787.36	3.41	0.31
	2230	78.69	866.30	787.61	3.41	0.31
	2240	79.00	866.85	787.85	3.41	0.31
	2250	79.31	867.40	788.10	3.41	0.31
	2260	79.61	867.95	788.34	3.41	0.31
	2270	79.92	868.49	788.58	3.41	0.31
	2280	80.23	869.04	788.81	3.41	0.31
	2290	80.53	869.57	789.04	3.41	0.31
	2300	80.84	870.11	789.27	3.41	0.31
	2310	81.15	870.64	789.50	3.41	0.31
	2320	81.45	871.17	789.72	3.41	0.31
	2330	81.76	871.70	789.94	3.41	0.31
	2340	82.07	872.23	790.16	3.41	0.31
	2350	82.38	872.75	790.37	3.41	0.31
	2360	82.68	873.27	790.58	3.41	0.31
	2370	82.99	873.78	790.79	3.41	0.31

	2380	83.30	874.30	791.00	3.41	0.31
	2390	83.61	874.81	791.20	3.41	0.31
40 Min.	2400	83.91	875.32	791.41	3.41	0.31
	2410	84.22	875.83	791.60	3.41	0.31
	2420	84.53	876.33	791.80	3.41	0.31
	2430	84.84	876.83	792.00	3.41	0.31
	2440	85.15	877.33	792.19	3.41	0.31
	2450	85.45	877.83	792.38	3.41	0.31
	2460	85.76	878.33	792.56	3.41	0.31
	2470	86.07	878.82	792.75	3.41	0.31
	2480	86.38	879.31	792.93	3.41	0.31
	2490	86.69	879.80	793.11	3.41	0.31
	2500	87.00	880.28	793.29	3.41	0.31
	2510	87.30	880.77	793.46	3.41	0.31
	2520	87.61	881.25	793.63	3.41	0.31
	2530	87.92	881.73	793.81	3.41	0.31
	2540	88.23	882.20	793.97	3.41	0.31
	2550	88.54	882.68	794.14	3.41	0.31
	2560	88.85	883.15	794.30	3.41	0.31
	2570	89.16	883.62	794.46	3.41	0.31
	2580	89.47	884.09	794.62	3.41	0.31
	2590	89.78	884.56	794.78	3.41	0.31
	2600	90.08	885.02	794.94	3.41	0.31
	2610	90.39	885.48	795.09	3.41	0.31
	2620	90.70	885.94	795.24	3.41	0.31
	2630	91.01	886.40	795.39	3.41	0.31
	2640	91.32	886.86	795.54	3.41	0.31
	2650	91.63	887.31	795.68	3.41	0.31
	2660	91.94	887.77	795.82	3.41	0.31
	2670	92.25	888.22	795.97	3.41	0.31
	2680	92.56	888.66	796.10	3.41	0.31

	2690	92.87	889.11	796.24	3.41	0.31
45 Min.	2700	93.18	889.56	796.38	3.41	0.31
	2710	93.49	890.00	796.51	3.41	0.31
	2720	93.80	890.44	796.64	3.41	0.31
	2730	94.11	890.88	796.77	3.41	0.31
	2740	94.42	891.32	796.90	3.41	0.31
	2750	94.73	891.75	797.02	3.41	0.31
	2760	95.04	892.19	797.15	3.41	0.31
	2770	95.35	892.62	797.27	3.41	0.31
	2780	95.66	893.05	797.39	3.41	0.31
	2790	95.97	893.48	797.51	3.41	0.31
	2800	96.28	893.90	797.63	3.41	0.31
	2810	96.59	894.33	797.74	3.41	0.31
	2820	96.90	894.75	797.85	3.41	0.31
	2830	97.21	895.17	797.97	3.41	0.31
	2840	97.52	895.60	798.07	3.41	0.31
	2850	97.83	896.01	798.18	3.41	0.31
	2860	98.14	896.43	798.29	3.41	0.31
	2870	98.45	896.85	798.39	3.41	0.31
	2880	98.76	897.26	798.50	3.41	0.31
	2890	99.07	897.67	798.60	3.41	0.31
	2900	99.38	898.08	798.70	3.41	0.31
	2910	99.69	898.49	798.80	3.41	0.31
	2920	100.00	898.90	798.89	3.41	0.31
	2930	100.32	899.30	798.99	3.41	0.31
	2940	100.63	899.71	799.08	3.41	0.31
	2950	100.94	900.11	799.17	3.41	0.31
	2960	101.25	900.51	799.26	3.41	0.31
	2970	101.56	900.91	799.35	3.41	0.31
	2980	101.87	901.31	799.44	3.41	0.31
	2990	102.18	901.71	799.53	3.41	0.31

50 Min.	3000	102.49	902.10	799.61	3.41	0.31
	3010	102.80	902.50	799.69	3.41	0.31
	3020	103.11	902.89	799.78	3.41	0.31
	3030	103.42	903.28	799.86	3.41	0.31
	3040	103.74	903.67	799.94	3.41	0.31
	3050	104.05	904.06	800.01	3.41	0.31
	3060	104.36	904.45	800.09	3.41	0.31
	3070	104.67	904.83	800.16	3.41	0.31
	3080	104.98	905.22	800.24	3.41	0.31
	3090	105.29	905.60	800.31	3.41	0.31
	3100	105.60	905.98	800.38	3.41	0.31
	3110	105.91	906.36	800.45	3.41	0.31
	3120	106.23	906.74	800.51	3.41	0.31
	3130	106.54	907.12	800.58	3.41	0.31
	3140	106.85	907.49	800.65	3.41	0.31
	3150	107.16	907.87	800.71	3.41	0.31
	3160	107.47	908.24	800.77	3.41	0.31
	3170	107.78	908.62	800.83	3.41	0.31
	3180	108.09	908.99	800.89	3.41	0.31
	3190	108.41	909.36	800.95	3.41	0.31
	3200	108.72	909.73	801.01	3.41	0.31
	3210	109.03	910.09	801.06	3.41	0.31
	3220	109.34	910.46	801.12	3.41	0.31
	3230	109.65	910.82	801.17	3.41	0.31
	3240	109.96	911.19	801.22	3.41	0.31
	3250	110.28	911.55	801.27	3.41	0.31
	3260	110.59	911.91	801.32	3.41	0.31
	3270	110.90	912.27	801.37	3.41	0.31
	3280	111.21	912.63	801.42	3.41	0.31
	3290	111.52	912.99	801.47	3.41	0.31
55 Min.	3300	111.83	913.35	801.51	3.41	0.31

	3310	112.15	913.70	801.56	3.41	0.31
	3320	112.46	914.06	801.60	3.41	0.31
	3330	112.77	914.41	801.64	3.41	0.31
	3340	113.08	914.76	801.68	3.41	0.31
	3350	113.39	915.11	801.72	3.41	0.31
	3360	113.71	915.46	801.76	3.41	0.31
	3370	114.02	915.81	801.80	3.41	0.31
	3380	114.33	916.16	801.83	3.41	0.31
	3390	114.64	916.51	801.87	3.41	0.31
	3400	114.95	916.85	801.90	3.41	0.31
	3410	115.26	917.20	801.93	3.41	0.31
	3420	115.58	917.54	801.97	3.41	0.31
	3430	115.89	917.88	802.00	3.41	0.31
	3440	116.20	918.23	802.03	3.41	0.31
	3450	116.51	918.57	802.05	3.41	0.31
	3460	116.82	918.91	802.08	3.41	0.31
	3470	117.14	919.24	802.11	3.41	0.31
	3480	117.45	919.58	802.13	3.41	0.31
	3490	117.76	919.92	802.16	3.41	0.31
	3500	118.07	920.25	802.18	3.41	0.31
	3510	118.38	920.59	802.20	3.41	0.31
	3520	118.70	920.92	802.23	3.41	0.31
	3530	119.01	921.26	802.25	3.41	0.31
	3540	119.32	921.59	802.27	3.41	0.31
	3550	119.63	921.92	802.28	3.41	0.31
	3560	119.94	922.25	802.30	3.41	0.31
	3570	120.26	922.58	802.32	3.41	0.31
	3580	120.57	922.90	802.33	3.41	0.31
	3590	120.88	923.23	802.35	3.41	0.31
1 Hour	3600	121.19	923.56	802.36	3.41	0.31
	3610	121.51	923.88	802.38	3.41	0.31

3620	121.82	924.21	802.39	3.41	0.31
3630	122.13	924.53	802.40	3.41	0.31
3640	122.44	924.85	802.41	3.41	0.31
3650	122.75	925.17	802.42	3.41	0.31
3660	123.07	925.49	802.43	3.41	0.31
3670	123.38	925.81	802.44	3.41	0.31
3680	123.69	926.13	802.44	3.41	0.31
3690	124.00	926.45	802.45	3.41	0.31
3700	124.31	926.77	802.45	3.41	0.31
3710	124.63	927.08	802.46	3.41	0.31
3720	124.94	927.40	802.46	3.41	0.31
3730	125.25	927.71	802.46	3.41	0.31
3740	125.56	928.03	802.46	3.41	0.31
3750	125.88	928.34	802.46	3.41	0.31
3760	126.19	928.65	802.46	3.41	0.31
3770	126.50	928.96	802.46	3.41	0.31
3780	126.81	929.27	802.46	3.41	0.31
3790	127.12	929.58	802.46	3.41	0.31
3800	127.44	929.89	802.46	3.41	0.31
3810	127.75	930.20	802.45	3.41	0.31
3820	128.06	930.51	802.45	3.41	0.31
3830	128.37	930.81	802.44	3.41	0.31
3840	128.68	931.12	802.43	3.41	0.31
3850	129.00	931.42	802.43	3.41	0.31
3860	129.31	931.73	802.42	3.41	0.31
3870	129.62	932.03	802.41	3.41	0.31
3880	129.93	932.33	802.40	3.41	0.31
3890	130.24	932.63	802.39	3.41	0.31
3900	130.56	932.93	802.38	3.41	0.31
3910	130.87	933.23	802.37	3.41	0.31
3920	131.18	933.53	802.35	3.41	0.31

3930	131.49	933.83	802.34	3.41	0.31
3940	131.81	934.13	802.33	3.41	0.31
3950	132.12	934.43	802.31	3.41	0.31
3960	132.43	934.72	802.29	3.41	0.31
3970	132.74	935.02	802.28	3.41	0.31
3980	133.05	935.31	802.26	3.41	0.31
3990	133.37	935.61	802.24	3.41	0.31
4000	133.68	935.90	802.23	3.41	0.31
4010	133.99	936.20	802.21	3.41	0.31
4020	134.30	936.49	802.19	3.41	0.31
4030	134.61	936.78	802.17	3.41	0.31
4040	134.93	937.07	802.14	3.41	0.31
4050	135.24	937.36	802.12	3.41	0.31
4060	135.55	937.65	802.10	3.41	0.31
4070	135.86	937.94	802.08	3.41	0.31
4080	136.17	938.23	802.05	3.41	0.31
4090	136.49	938.51	802.03	3.41	0.31
4100	136.80	938.80	802.00	3.41	0.31
4110	137.11	939.09	801.98	3.41	0.31
4120	137.42	939.37	801.95	3.41	0.31
4130	137.73	939.66	801.92	3.41	0.31
4140	138.05	939.94	801.89	3.41	0.31
4150	138.36	940.22	801.87	3.41	0.31
4160	138.67	940.51	801.84	3.41	0.31
4170	138.98	940.79	801.81	3.41	0.31
4180	139.29	941.07	801.78	3.41	0.31
4190	139.61	941.35	801.74	3.41	0.31
4200	139.92	941.63	801.71	3.41	0.31
4210	140.23	941.91	801.68	3.41	0.31
4220	140.54	942.19	801.65	3.41	0.31
4230	140.85	942.47	801.61	3.41	0.31

4240	141.16	942.74	801.58	3.41	0.31
4250	141.48	943.02	801.55	3.41	0.31
4260	141.79	943.30	801.51	3.41	0.31
4270	142.10	943.57	801.47	3.41	0.31
4280	142.41	943.85	801.44	3.41	0.31
4290	142.72	944.12	801.40	3.41	0.31
4300	143.03	944.40	801.36	3.41	0.31
4310	143.35	944.67	801.32	3.41	0.31
4320	143.66	944.94	801.29	3.41	0.31
4330	143.97	945.22	801.25	3.41	0.31
4340	144.28	945.49	801.21	3.41	0.31
4350	144.59	945.76	801.17	3.41	0.31
4360	144.90	946.03	801.12	3.41	0.31
4370	145.22	946.30	801.08	3.41	0.31
4380	145.53	946.57	801.04	3.41	0.31
4390	145.84	946.84	801.00	3.41	0.31
4400	146.15	947.10	800.95	3.41	0.31
4410	146.46	947.37	800.91	3.41	0.31
4420	146.77	947.64	800.87	3.41	0.31
4430	147.09	947.91	800.82	3.41	0.31
4440	147.40	948.17	800.77	3.41	0.31
4450	147.71	948.44	800.73	3.41	0.31
4460	148.02	948.70	800.68	3.41	0.31
4470	148.33	948.97	800.64	3.41	0.31
4480	148.64	949.23	800.59	3.41	0.31
4490	148.95	949.49	800.54	3.41	0.31
4500	149.27	949.76	800.49	3.41	0.31
4510	149.58	950.02	800.44	3.41	0.31
4520	149.89	950.28	800.39	3.41	0.31
4530	150.20	950.54	800.34	3.41	0.31
4540	150.51	950.80	800.29	3.41	0.31

4550	150.82	951.06	800.24	3.41	0.31
4560	151.13	951.32	800.19	3.41	0.31
4570	151.44	951.58	800.14	3.41	0.31
4580	151.76	951.84	800.08	3.41	0.31
4590	152.07	952.10	800.03	3.41	0.31
4600	152.38	952.36	799.98	3.41	0.31
4610	152.69	952.61	799.92	3.41	0.31
4620	153.00	952.87	799.87	3.41	0.31
4630	153.31	953.12	799.81	3.41	0.31
4640	153.62	953.38	799.76	3.41	0.31
4650	153.93	953.64	799.70	3.41	0.31
4660	154.25	953.89	799.64	3.41	0.31
4670	154.56	954.14	799.59	3.41	0.31
4680	154.87	954.40	799.53	3.41	0.31
4690	155.18	954.65	799.47	3.41	0.31
4700	155.49	954.90	799.41	3.41	0.31
4710	155.80	955.16	799.36	3.41	0.31
4720	156.11	955.41	799.30	3.41	0.31
4730	156.42	955.66	799.24	3.41	0.31
4740	156.73	955.91	799.18	3.41	0.31
4750	157.04	956.16	799.12	3.41	0.31
4760	157.35	956.41	799.05	3.41	0.31
4770	157.67	956.66	798.99	3.41	0.31
4780	157.98	956.91	798.93	3.41	0.31
4790	158.29	957.16	798.87	3.41	0.31
4800	158.60	957.40	798.81	3.41	0.31
4810	158.91	957.65	798.74	3.41	0.31
4820	159.22	957.90	798.68	3.41	0.31
4830	159.53	958.15	798.62	3.41	0.31
4840	159.84	958.39	798.55	3.41	0.31
4850	160.15	958.64	798.49	3.41	0.31

4860	160.46	958.88	798.42	3.41	0.31
4870	160.77	959.13	798.35	3.41	0.31
4880	161.08	959.37	798.29	3.41	0.31
4890	161.39	959.62	798.22	3.41	0.31
4900	161.70	959.86	798.16	3.41	0.31
4910	162.01	960.10	798.09	3.41	0.31
4920	162.32	960.34	798.02	3.41	0.31
4930	162.64	960.59	797.95	3.41	0.31
4940	162.95	960.83	797.88	3.41	0.31
4950	163.26	961.07	797.81	3.41	0.31
4960	163.57	961.31	797.75	3.41	0.31
4970	163.88	961.55	797.68	3.41	0.31
4980	164.19	961.79	797.61	3.41	0.31
4990	164.50	962.03	797.53	3.41	0.31
5000	164.81	962.27	797.46	3.41	0.31
5010	165.12	962.51	797.39	3.41	0.31
5020	165.43	962.75	797.32	3.41	0.31
5030	165.74	962.99	797.25	3.41	0.31
5040	166.05	963.22	797.18	3.41	0.31
5050	166.36	963.46	797.10	3.41	0.31
5060	166.67	963.70	797.03	3.41	0.31
5070	166.98	963.93	796.96	3.41	0.31
5080	167.29	964.17	796.88	3.41	0.31
5090	167.60	964.41	796.81	3.41	0.31
5100	167.91	964.64	796.73	3.41	0.31
5110	168.22	964.88	796.66	3.41	0.31
5120	168.53	965.11	796.58	3.41	0.31
5130	168.84	965.35	796.51	3.41	0.31
5140	169.15	965.58	796.43	3.41	0.31
5150	169.46	965.81	796.36	3.41	0.31
5160	169.77	966.05	796.28	3.41	0.31

5170	170.08	966.28	796.20	3.41	0.31
5180	170.39	966.51	796.12	3.41	0.31
5190	170.70	966.74	796.05	3.41	0.31
5200	171.01	966.97	795.97	3.41	0.31
5210	171.32	967.20	795.89	3.41	0.31
5220	171.62	967.44	795.81	3.41	0.31
5230	171.93	967.67	795.73	3.41	0.31
5240	172.24	967.90	795.65	3.41	0.31
5250	172.55	968.13	795.57	3.41	0.31
5260	172.86	968.35	795.49	3.41	0.31
5270	173.17	968.58	795.41	3.41	0.31
5280	173.48	968.81	795.33	3.41	0.31
5290	173.79	969.04	795.25	3.41	0.31
5300	174.10	969.27	795.17	3.41	0.31
5310	174.41	969.50	795.09	3.41	0.31
5320	174.72	969.72	795.00	3.41	0.31
5330	175.03	969.95	794.92	3.41	0.31
5340	175.34	970.18	794.84	3.41	0.31
5350	175.65	970.40	794.76	3.41	0.31
5360	175.96	970.63	794.67	3.41	0.31
5370	176.26	970.85	794.59	3.41	0.31
5380	176.57	971.08	794.50	3.41	0.31
5390	176.88	971.30	794.42	3.41	0.31
5400	177.19	971.53	794.34	3.41	0.31
5410	177.50	971.75	794.25	3.41	0.31
5420	177.81	971.97	794.17	3.41	0.31
5430	178.12	972.20	794.08	3.41	0.31
5440	178.43	972.42	793.99	3.41	0.31
5450	178.74	972.64	793.91	3.41	0.31
5460	179.05	972.87	793.82	3.41	0.31
5470	179.35	973.09	793.73	3.41	0.31

5480	179.66	973.31	793.65	3.41	0.31
5490	179.97	973.53	793.56	3.41	0.31
5500	180.28	973.75	793.47	3.41	0.31
5510	180.59	973.97	793.38	3.41	0.31
5520	180.90	974.19	793.30	3.41	0.31
5530	181.21	974.41	793.21	3.41	0.31
5540	181.51	974.63	793.12	3.41	0.31
5550	181.82	974.85	793.03	3.41	0.31
5560	182.13	975.07	792.94	3.41	0.31
5570	182.44	975.29	792.85	3.41	0.31
5580	182.75	975.51	792.76	3.41	0.31
5590	183.06	975.73	792.67	3.41	0.31
5600	183.36	975.94	792.58	3.41	0.31
5610	183.67	976.16	792.49	3.41	0.31
5620	183.98	976.38	792.40	3.41	0.31
5630	184.29	976.60	792.31	3.41	0.31
5640	184.60	976.81	792.21	3.41	0.31
5650	184.91	977.03	792.12	3.41	0.31
5660	185.21	977.24	792.03	3.41	0.31
5670	185.52	977.46	791.94	3.41	0.31
5680	185.83	977.68	791.85	3.41	0.31
5690	186.14	977.89	791.75	3.41	0.31
5700	186.45	978.11	791.66	3.41	0.31
5710	186.75	978.32	791.57	3.41	0.31
5720	187.06	978.53	791.47	3.41	0.31
5730	187.37	978.75	791.38	3.41	0.31
5740	187.68	978.96	791.28	3.41	0.31
5750	187.99	979.17	791.19	3.41	0.31
5760	188.29	979.39	791.09	3.41	0.31
5770	188.60	979.60	791.00	3.41	0.31
5780	188.91	979.81	790.90	3.41	0.31

5790	189.22	980.02	790.81	3.41	0.31
5800	189.52	980.24	790.71	3.41	0.31
5810	189.83	980.45	790.62	3.41	0.31
5820	190.14	980.66	790.52	3.41	0.31
5830	190.45	980.87	790.42	3.41	0.31
5840	190.75	981.08	790.33	3.41	0.31
5850	191.06	981.29	790.23	3.41	0.31
5860	191.37	981.50	790.13	3.41	0.31
5870	191.68	981.71	790.03	3.41	0.31
5880	191.98	981.92	789.94	3.41	0.31
5890	192.29	982.13	789.84	3.41	0.31
5900	192.60	982.34	789.74	3.41	0.31
5910	192.91	982.55	789.64	3.41	0.31
5920	193.21	982.76	789.54	3.41	0.31
5930	193.52	982.96	789.44	3.41	0.31
5940	193.83	983.17	789.35	3.41	0.31
5950	194.13	983.38	789.25	3.41	0.31
5960	194.44	983.59	789.15	3.41	0.31
5970	194.75	983.79	789.05	3.41	0.31
5980	195.05	984.00	788.95	3.41	0.31
5990	195.36	984.21	788.85	3.41	0.31
6000	195.67	984.41	788.75	3.41	0.31
6010	195.97	984.62	788.64	3.41	0.31
6020	196.28	984.83	788.54	3.41	0.31
6030	196.59	985.03	788.44	3.41	0.31
6040	196.90	985.24	788.34	3.41	0.31
6050	197.20	985.44	788.24	3.41	0.31
6060	197.51	985.65	788.14	3.41	0.31
6070	197.81	985.85	788.04	3.41	0.31
6080	198.12	986.05	787.93	3.41	0.31
6090	198.43	986.26	787.83	3.41	0.31

6100	198.73	986.46	787.73	3.41	0.31
6110	199.04	986.67	787.62	3.41	0.31
6120	199.35	986.87	787.52	3.41	0.31
6130	199.65	987.07	787.42	3.41	0.31
6140	199.96	987.27	787.31	3.41	0.31
6150	200.27	987.48	787.21	3.41	0.31
6160	200.57	987.68	787.11	3.41	0.31
6170	200.88	987.88	787.00	3.41	0.31
6180	201.18	988.08	786.90	3.41	0.31
6190	201.49	988.28	786.79	3.41	0.31
6200	201.80	988.48	786.69	3.41	0.31
6210	202.10	988.69	786.58	3.41	0.31
6220	202.41	988.89	786.48	3.41	0.31
6230	202.71	989.09	786.37	3.41	0.31
6240	203.02	989.29	786.27	3.41	0.31
6250	203.33	989.49	786.16	3.41	0.31
6260	203.63	989.69	786.05	3.41	0.31
6270	203.94	989.89	785.95	3.41	0.31
6280	204.24	990.09	785.84	3.41	0.31
6290	204.55	990.28	785.74	3.41	0.31
6300	204.85	990.48	785.63	3.41	0.31
6310	205.16	990.68	785.52	3.41	0.31
6320	205.47	990.88	785.41	3.41	0.31
6330	205.77	991.08	785.31	3.41	0.31
6340	206.08	991.28	785.20	3.41	0.31
6350	206.38	991.47	785.09	3.41	0.31
6360	206.69	991.67	784.98	3.41	0.31
6370	206.99	991.87	784.87	3.41	0.31
6380	207.30	992.06	784.77	3.41	0.31
6390	207.60	992.26	784.66	3.41	0.31
6400	207.91	992.46	784.55	3.41	0.31

6410	208.21	992.65	784.44	3.41	0.31
6420	208.52	992.85	784.33	3.41	0.31
6430	208.82	993.05	784.22	3.41	0.31
6440	209.13	993.24	784.11	3.41	0.30
6450	209.43	993.44	784.00	3.41	0.30
6460	209.74	993.63	783.89	3.41	0.30
6470	210.04	993.83	783.78	3.41	0.30
6480	210.35	994.02	783.67	3.41	0.30
6490	210.65	994.22	783.56	3.41	0.30
6500	210.96	994.41	783.45	3.41	0.30
6510	211.26	994.60	783.34	3.41	0.30
6520	211.57	994.80	783.23	3.41	0.30
6530	211.87	994.99	783.12	3.41	0.30
6540	212.18	995.18	783.01	3.41	0.30
6550	212.48	995.38	782.90	3.41	0.30
6560	212.79	995.57	782.78	3.41	0.30
6570	213.09	995.76	782.67	3.41	0.30
6580	213.40	995.96	782.56	3.41	0.30
6590	213.70	996.15	782.45	3.41	0.30
6600	214.00	996.34	782.34	3.41	0.30
6610	214.31	996.53	782.22	3.41	0.30
6620	214.61	996.72	782.11	3.41	0.30
6630	214.92	996.91	782.00	3.41	0.30
6640	215.22	997.11	781.88	3.41	0.30
6650	215.53	997.30	781.77	3.41	0.30
6660	215.83	997.49	781.66	3.41	0.30
6670	216.13	997.68	781.54	3.41	0.30
6680	216.44	997.87	781.43	3.41	0.30
6690	216.74	998.06	781.32	3.41	0.30
6700	217.05	998.25	781.20	3.41	0.30
6710	217.35	998.44	781.09	3.41	0.30

6720	217.65	998.63	780.97	3.41	0.30
6730	217.96	998.82	780.86	3.41	0.30
6740	218.26	999.01	780.75	3.41	0.30
6750	218.56	999.19	780.63	3.41	0.30
6760	218.87	999.38	780.52	3.41	0.30
6770	219.17	999.57	780.40	3.41	0.30
6780	219.47	999.76	780.29	3.41	0.30
6790	219.78	999.95	780.17	3.41	0.30
6800	220.08	1000.14	780.05	3.41	0.30
6810	220.39	1000.32	779.94	3.41	0.30
6820	220.69	1000.51	779.82	3.41	0.30
6830	220.99	1000.70	779.71	3.41	0.30
6840	221.30	1000.89	779.59	3.41	0.30
6850	221.60	1001.07	779.47	3.41	0.30
6860	221.90	1001.26	779.36	3.41	0.30
6870	222.20	1001.45	779.24	3.41	0.30
6880	222.51	1001.63	779.12	3.41	0.30
6890	222.81	1001.82	779.01	3.41	0.30
6900	223.11	1002.00	778.89	3.41	0.30
6910	223.42	1002.19	778.77	3.41	0.30
6920	223.72	1002.38	778.66	3.41	0.30
6930	224.02	1002.56	778.54	3.41	0.30
6940	224.33	1002.75	778.42	3.41	0.30
6950	224.63	1002.93	778.30	3.41	0.30
6960	224.93	1003.12	778.19	3.41	0.30
6970	225.23	1003.30	778.07	3.41	0.30
6980	225.54	1003.49	777.95	3.41	0.30
6990	225.84	1003.67	777.83	3.41	0.30
7000	226.14	1003.85	777.71	3.41	0.30
7010	226.44	1004.04	777.59	3.41	0.30
7020	226.75	1004.22	777.48	3.41	0.30

	7030	227.05	1004.41	777.36	3.41	0.30
	7040	227.35	1004.59	777.24	3.41	0.30
	7050	227.65	1004.77	777.12	3.41	0.30
	7060	227.96	1004.95	777.00	3.41	0.30
	7070	228.26	1005.14	776.88	3.41	0.30
	7080	228.56	1005.32	776.76	3.41	0.30
	7090	228.86	1005.50	776.64	3.41	0.30
	7100	229.16	1005.68	776.52	3.41	0.30
	7110	229.47	1005.87	776.40	3.41	0.30
	7120	229.77	1006.05	776.28	3.41	0.30
	7130	230.07	1006.23	776.16	3.41	0.30
	7140	230.37	1006.41	776.04	3.41	0.30
	7150	230.67	1006.59	775.92	3.41	0.30
	7160	230.98	1006.77	775.80	3.41	0.30
	7170	231.28	1006.96	775.68	3.41	0.30
	7180	231.58	1007.14	775.56	3.41	0.30
	7190	231.88	1007.32	775.44	3.41	0.30
2 Hour	7200	232.18	1007.50	775.31	3.41	0.30
	7210	232.48	1007.68	775.19	3.41	0.30
	7220	232.79	1007.86	775.07	3.41	0.30
	7230	233.09	1008.04	774.95	3.41	0.30
	7240	233.39	1008.22	774.83	3.41	0.30
	7250	233.69	1008.40	774.71	3.41	0.30
	7260	233.99	1008.58	774.59	3.41	0.30
	7270	234.29	1008.76	774.46	3.41	0.30
	7280	234.59	1008.94	774.34	3.41	0.30
	7290	234.90	1009.11	774.22	3.41	0.30
	7300	235.20	1009.29	774.10	3.41	0.30
	7310	235.50	1009.47	773.97	3.41	0.30
	7320	235.80	1009.65	773.85	3.41	0.30
	7330	236.10	1009.83	773.73	3.41	0.30

7340	236.40	1010.01	773.61	3.41	0.30
7350	236.70	1010.18	773.48	3.41	0.30
7360	237.00	1010.36	773.36	3.41	0.30
7370	237.30	1010.54	773.24	3.41	0.30
7380	237.60	1010.72	773.11	3.41	0.30
7390	237.90	1010.89	772.99	3.41	0.30
7400	238.21	1011.07	772.87	3.41	0.30
7410	238.51	1011.25	772.74	3.41	0.30
7420	238.81	1011.43	772.62	3.41	0.30
7430	239.11	1011.60	772.49	3.41	0.30
7440	239.41	1011.78	772.37	3.41	0.30
7450	239.71	1011.95	772.25	3.41	0.30
7460	240.01	1012.13	772.12	3.41	0.30
7470	240.31	1012.31	772.00	3.41	0.30
7480	240.61	1012.48	771.87	3.41	0.30
7490	240.91	1012.66	771.75	3.41	0.30
7500	241.21	1012.83	771.62	3.41	0.30
7510	241.51	1013.01	771.50	3.41	0.30
7520	241.81	1013.18	771.37	3.41	0.30
7530	242.11	1013.36	771.25	3.41	0.30
7540	242.41	1013.53	771.12	3.41	0.30
7550	242.71	1013.71	771.00	3.41	0.30
7560	243.01	1013.88	770.87	3.41	0.30
7570	243.31	1014.06	770.75	3.41	0.30
7580	243.61	1014.23	770.62	3.41	0.30
7590	243.91	1014.41	770.50	3.41	0.30
7600	244.21	1014.58	770.37	3.41	0.30
7610	244.51	1014.75	770.25	3.41	0.30
7620	244.81	1014.93	770.12	3.41	0.30
7630	245.11	1015.10	769.99	3.41	0.30
7640	245.41	1015.27	769.87	3.41	0.30

7650	245.71	1015.45	769.74	3.41	0.30
7660	246.01	1015.62	769.61	3.41	0.30
7670	246.31	1015.79	769.49	3.41	0.30
7680	246.60	1015.97	769.36	3.41	0.30
7690	246.90	1016.14	769.23	3.41	0.30
7700	247.20	1016.31	769.11	3.41	0.30
7710	247.50	1016.48	768.98	3.41	0.30
7720	247.80	1016.66	768.85	3.41	0.30
7730	248.10	1016.83	768.73	3.41	0.30
7740	248.40	1017.00	768.60	3.41	0.30
7750	248.70	1017.17	768.47	3.41	0.30
7760	249.00	1017.34	768.34	3.41	0.30
7770	249.30	1017.51	768.22	3.41	0.30
7780	249.59	1017.68	768.09	3.41	0.30
7790	249.89	1017.86	767.96	3.41	0.30
7800	250.19	1018.03	767.83	3.41	0.30
7810	250.49	1018.20	767.71	3.41	0.30
7820	250.79	1018.37	767.58	3.41	0.30
7830	251.09	1018.54	767.45	3.41	0.30
7840	251.39	1018.71	767.32	3.41	0.30
7850	251.69	1018.88	767.19	3.41	0.30
7860	251.98	1019.05	767.07	3.41	0.30
7870	252.28	1019.22	766.94	3.41	0.30
7880	252.58	1019.39	766.81	3.41	0.30
7890	252.88	1019.56	766.68	3.41	0.30
7900	253.18	1019.73	766.55	3.41	0.30
7910	253.47	1019.90	766.42	3.41	0.30
7920	253.77	1020.07	766.29	3.41	0.30
7930	254.07	1020.24	766.16	3.41	0.30
7940	254.37	1020.40	766.04	3.41	0.30
7950	254.67	1020.57	765.91	3.41	0.30

7960	254.97	1020.74	765.78	3.41	0.30
7970	255.26	1020.91	765.65	3.41	0.30
7980	255.56	1021.08	765.52	3.41	0.30
7990	255.86	1021.25	765.39	3.41	0.30
8000	256.16	1021.42	765.26	3.41	0.30
8010	256.45	1021.58	765.13	3.41	0.30
8020	256.75	1021.75	765.00	3.41	0.30
8030	257.05	1021.92	764.87	3.41	0.30
8040	257.35	1022.09	764.74	3.41	0.30
8050	257.64	1022.25	764.61	3.41	0.30
8060	257.94	1022.42	764.48	3.41	0.30
8070	258.24	1022.59	764.35	3.41	0.30
8080	258.54	1022.76	764.22	3.41	0.30
8090	258.83	1022.92	764.09	3.41	0.30
8100	259.13	1023.09	763.96	3.41	0.30
8110	259.43	1023.26	763.83	3.41	0.30
8120	259.72	1023.42	763.70	3.41	0.30
8130	260.02	1023.59	763.57	3.41	0.30
8140	260.32	1023.75	763.44	3.41	0.30
8150	260.62	1023.92	763.30	3.41	0.30
8160	260.91	1024.09	763.17	3.41	0.30
8170	261.21	1024.25	763.04	3.41	0.30
8180	261.51	1024.42	762.91	3.41	0.30
8190	261.80	1024.58	762.78	3.41	0.30
8200	262.10	1024.75	762.65	3.41	0.30
8210	262.40	1024.91	762.52	3.41	0.30
8220	262.69	1025.08	762.39	3.41	0.30
8230	262.99	1025.24	762.25	3.41	0.30
8240	263.29	1025.41	762.12	3.41	0.30
8250	263.58	1025.57	761.99	3.41	0.30
8260	263.88	1025.74	761.86	3.41	0.30

8270	264.18	1025.90	761.73	3.41	0.30
8280	264.47	1026.07	761.60	3.41	0.30
8290	264.77	1026.23	761.46	3.41	0.30
8300	265.06	1026.40	761.33	3.41	0.30
8310	265.36	1026.56	761.20	3.41	0.30
8320	265.66	1026.72	761.07	3.41	0.30
8330	265.95	1026.89	760.93	3.41	0.30
8340	266.25	1027.05	760.80	3.41	0.30
8350	266.54	1027.21	760.67	3.41	0.30
8360	266.84	1027.38	760.54	3.41	0.30
8370	267.14	1027.54	760.40	3.41	0.30
8380	267.43	1027.70	760.27	3.41	0.30
8390	267.73	1027.87	760.14	3.41	0.30
8400	268.02	1028.03	760.01	3.41	0.30
8410	268.32	1028.19	759.87	3.41	0.30
8420	268.61	1028.36	759.74	3.41	0.30
8430	268.91	1028.52	759.61	3.41	0.30
8440	269.21	1028.68	759.47	3.41	0.30
8450	269.50	1028.84	759.34	3.41	0.30
8460	269.80	1029.00	759.21	3.41	0.30
8470	270.09	1029.17	759.07	3.41	0.30
8480	270.39	1029.33	758.94	3.41	0.30
8490	270.68	1029.49	758.81	3.41	0.30
8500	270.98	1029.65	758.67	3.41	0.30
8510	271.27	1029.81	758.54	3.41	0.30
8520	271.57	1029.97	758.41	3.41	0.30
8530	271.86	1030.14	758.27	3.41	0.29
8540	272.16	1030.30	758.14	3.41	0.29
8550	272.45	1030.46	758.01	3.41	0.29
8560	272.75	1030.62	757.87	3.41	0.29
8570	273.04	1030.78	757.74	3.41	0.29

8580	273.34	1030.94	757.60	3.41	0.29
8590	273.63	1031.10	757.47	3.41	0.29
8600	273.93	1031.26	757.34	3.41	0.29
8610	274.22	1031.42	757.20	3.41	0.29
8620	274.51	1031.58	757.07	3.41	0.29
8630	274.81	1031.74	756.93	3.41	0.29
8640	275.10	1031.90	756.80	3.41	0.29
8650	275.40	1032.06	756.66	3.41	0.29
8660	275.69	1032.22	756.53	3.41	0.29
8670	275.99	1032.38	756.39	3.41	0.29
8680	276.28	1032.54	756.26	3.41	0.29
8690	276.58	1032.70	756.12	3.41	0.29
8700	276.87	1032.86	755.99	3.41	0.29
8710	277.16	1033.02	755.86	3.41	0.29
8720	277.46	1033.18	755.72	3.41	0.29
8730	277.75	1033.34	755.59	3.41	0.29
8740	278.05	1033.50	755.45	3.41	0.29
8750	278.34	1033.65	755.31	3.41	0.29
8760	278.63	1033.81	755.18	3.41	0.29
8770	278.93	1033.97	755.04	3.41	0.29
8780	279.22	1034.13	754.91	3.41	0.29
8790	279.51	1034.29	754.77	3.41	0.29
8800	279.81	1034.45	754.64	3.41	0.29
8810	280.10	1034.60	754.50	3.41	0.29
8820	280.39	1034.76	754.37	3.41	0.29
8830	280.69	1034.92	754.23	3.41	0.29
8840	280.98	1035.08	754.10	3.41	0.29
8850	281.27	1035.23	753.96	3.41	0.29
8860	281.57	1035.39	753.82	3.41	0.29
8870	281.86	1035.55	753.69	3.41	0.29
8880	282.15	1035.71	753.55	3.41	0.29

8890	282.45	1035.86	753.42	3.41	0.29
8900	282.74	1036.02	753.28	3.41	0.29
8910	283.03	1036.18	753.14	3.41	0.29
8920	283.33	1036.33	753.01	3.41	0.29
8930	283.62	1036.49	752.87	3.41	0.29
8940	283.91	1036.65	752.74	3.41	0.29
8950	284.20	1036.80	752.60	3.41	0.29
8960	284.50	1036.96	752.46	3.41	0.29
8970	284.79	1037.12	752.33	3.41	0.29
8980	285.08	1037.27	752.19	3.41	0.29
8990	285.38	1037.43	752.05	3.41	0.29
9000	285.67	1037.59	751.92	3.41	0.29
9010	285.96	1037.74	751.78	3.41	0.29
9020	286.25	1037.90	751.64	3.41	0.29
9030	286.55	1038.05	751.51	3.41	0.29
9040	286.84	1038.21	751.37	3.41	0.29
9050	287.13	1038.36	751.23	3.41	0.29
9060	287.42	1038.52	751.10	3.41	0.29
9070	287.71	1038.67	750.96	3.41	0.29
9080	288.01	1038.83	750.82	3.41	0.29
9090	288.30	1038.98	750.69	3.41	0.29
9100	288.59	1039.14	750.55	3.41	0.29
9110	288.88	1039.29	750.41	3.41	0.29
9120	289.17	1039.45	750.27	3.41	0.29
9130	289.47	1039.60	750.14	3.41	0.29
9140	289.76	1039.76	750.00	3.41	0.29
9150	290.05	1039.91	749.86	3.41	0.29
9160	290.34	1040.07	749.72	3.41	0.29
9170	290.63	1040.22	749.59	3.41	0.29
9180	290.92	1040.37	749.45	3.41	0.29
9190	291.22	1040.53	749.31	3.41	0.29

9200	291.51	1040.68	749.17	3.41	0.29
9210	291.80	1040.84	749.04	3.41	0.29
9220	292.09	1040.99	748.90	3.41	0.29
9230	292.38	1041.14	748.76	3.41	0.29
9240	292.67	1041.30	748.62	3.41	0.29
9250	292.96	1041.45	748.49	3.41	0.29
9260	293.26	1041.60	748.35	3.41	0.29
9270	293.55	1041.76	748.21	3.41	0.29
9280	293.84	1041.91	748.07	3.41	0.29
9290	294.13	1042.06	747.93	3.41	0.29
9300	294.42	1042.21	747.80	3.41	0.29
9310	294.71	1042.37	747.66	3.41	0.29
9320	295.00	1042.52	747.52	3.41	0.29
9330	295.29	1042.67	747.38	3.41	0.29
9340	295.58	1042.82	747.24	3.41	0.29
9350	295.87	1042.98	747.10	3.41	0.29
9360	296.16	1043.13	746.97	3.41	0.29
9370	296.45	1043.28	746.83	3.41	0.29
9380	296.74	1043.43	746.69	3.41	0.29
9390	297.04	1043.59	746.55	3.41	0.29
9400	297.33	1043.74	746.41	3.41	0.29
9410	297.62	1043.89	746.27	3.41	0.29
9420	297.91	1044.04	746.13	3.41	0.29
9430	298.20	1044.19	746.00	3.41	0.29
9440	298.49	1044.34	745.86	3.41	0.29
9450	298.78	1044.49	745.72	3.41	0.29
9460	299.07	1044.65	745.58	3.41	0.29
9470	299.36	1044.80	745.44	3.41	0.29
9480	299.65	1044.95	745.30	3.41	0.29
9490	299.94	1045.10	745.16	3.41	0.29
9500	300.23	1045.25	745.02	3.41	0.29

9510	300.52	1045.40	744.88	3.41	0.29
9520	300.81	1045.55	744.75	3.41	0.29
9530	301.10	1045.70	744.61	3.41	0.29
9540	301.39	1045.85	744.47	3.41	0.29
9550	301.67	1046.00	744.33	3.41	0.29
9560	301.96	1046.15	744.19	3.41	0.29
9570	302.25	1046.30	744.05	3.41	0.29
9580	302.54	1046.45	743.91	3.41	0.29
9590	302.83	1046.60	743.77	3.41	0.29
9600	303.12	1046.75	743.63	3.41	0.29
9610	303.41	1046.90	743.49	3.41	0.29
9620	303.70	1047.05	743.35	3.41	0.29
9630	303.99	1047.20	743.21	3.41	0.29
9640	304.28	1047.35	743.07	3.41	0.29
9650	304.57	1047.50	742.93	3.41	0.29
9660	304.86	1047.65	742.79	3.41	0.29
9670	305.15	1047.80	742.65	3.41	0.29
9680	305.43	1047.95	742.51	3.41	0.29
9690	305.72	1048.10	742.38	3.41	0.29
9700	306.01	1048.25	742.24	3.41	0.29
9710	306.30	1048.40	742.10	3.41	0.29
9720	306.59	1048.54	741.96	3.41	0.29
9730	306.88	1048.69	741.82	3.41	0.29
9740	307.17	1048.84	741.68	3.41	0.29
9750	307.45	1048.99	741.54	3.41	0.29
9760	307.74	1049.14	741.40	3.41	0.29
9770	308.03	1049.29	741.26	3.41	0.29
9780	308.32	1049.44	741.12	3.41	0.29
9790	308.61	1049.58	740.98	3.41	0.29
9800	308.90	1049.73	740.84	3.41	0.29
9810	309.18	1049.88	740.70	3.41	0.29

9820	309.47	1050.03	740.56	3.41	0.29
9830	309.76	1050.18	740.41	3.41	0.29
9840	310.05	1050.32	740.27	3.41	0.29
9850	310.34	1050.47	740.13	3.41	0.29
9860	310.62	1050.62	739.99	3.41	0.29
9870	310.91	1050.77	739.85	3.41	0.29
9880	311.20	1050.91	739.71	3.41	0.29
9890	311.49	1051.06	739.57	3.41	0.29
9900	311.78	1051.21	739.43	3.41	0.29
9910	312.06	1051.35	739.29	3.41	0.29
9920	312.35	1051.50	739.15	3.41	0.29
9930	312.64	1051.65	739.01	3.41	0.29
9940	312.93	1051.80	738.87	3.41	0.29
9950	313.21	1051.94	738.73	3.41	0.29
9960	313.50	1052.09	738.59	3.41	0.29
9970	313.79	1052.24	738.45	3.41	0.29
9980	314.08	1052.38	738.31	3.41	0.29
9990	314.36	1052.53	738.17	3.41	0.29
10000	314.65	1052.67	738.03	3.41	0.29
10010	314.94	1052.82	737.88	3.41	0.29
10020	315.22	1052.97	737.74	3.41	0.29
10030	315.51	1053.11	737.60	3.41	0.29
10040	315.80	1053.26	737.46	3.41	0.29
10050	316.08	1053.40	737.32	3.41	0.29
10060	316.37	1053.55	737.18	3.41	0.29
10070	316.66	1053.70	737.04	3.41	0.29
10080	316.94	1053.84	736.90	3.41	0.29
10090	317.23	1053.99	736.76	3.41	0.29
10100	317.52	1054.13	736.62	3.41	0.29
10110	317.80	1054.28	736.47	3.41	0.29
10120	318.09	1054.42	736.33	3.41	0.29

10130	318.38	1054.57	736.19	3.41	0.29
10140	318.66	1054.71	736.05	3.41	0.29
10150	318.95	1054.86	735.91	3.41	0.29
10160	319.24	1055.00	735.77	3.41	0.29
10170	319.52	1055.15	735.63	3.41	0.29
10180	319.81	1055.29	735.48	3.41	0.29
10190	320.09	1055.44	735.34	3.41	0.29
10200	320.38	1055.58	735.20	3.41	0.29
10210	320.67	1055.73	735.06	3.41	0.29
10220	320.95	1055.87	734.92	3.41	0.29
10230	321.24	1056.02	734.78	3.41	0.29
10240	321.52	1056.16	734.64	3.41	0.29
10250	321.81	1056.30	734.49	3.41	0.29
10260	322.10	1056.45	734.35	3.41	0.29
10270	322.38	1056.59	734.21	3.41	0.29
10280	322.67	1056.74	734.07	3.41	0.29
10290	322.95	1056.88	733.93	3.41	0.29
10300	323.24	1057.02	733.79	3.41	0.29
10310	323.52	1057.17	733.64	3.41	0.29
10320	323.81	1057.31	733.50	3.41	0.29
10330	324.09	1057.45	733.36	3.41	0.29
10340	324.38	1057.60	733.22	3.41	0.29
10350	324.66	1057.74	733.08	3.41	0.29
10360	324.95	1057.88	732.94	3.41	0.29
10370	325.23	1058.03	732.79	3.41	0.29
10380	325.52	1058.17	732.65	3.41	0.28
10390	325.80	1058.31	732.51	3.41	0.28
10400	326.09	1058.46	732.37	3.41	0.28
10410	326.37	1058.60	732.23	3.41	0.28
10420	326.66	1058.74	732.08	3.41	0.28
10430	326.94	1058.89	731.94	3.41	0.28

10440	327.23	1059.03	731.80	3.41	0.28
10450	327.51	1059.17	731.66	3.41	0.28
10460	327.80	1059.31	731.52	3.41	0.28
10470	328.08	1059.46	731.37	3.41	0.28
10480	328.37	1059.60	731.23	3.41	0.28
10490	328.65	1059.74	731.09	3.41	0.28
10500	328.94	1059.88	730.95	3.41	0.28
10510	329.22	1060.02	730.80	3.41	0.28
10520	329.50	1060.17	730.66	3.41	0.28
10530	329.79	1060.31	730.52	3.41	0.28
10540	330.07	1060.45	730.38	3.41	0.28
10550	330.36	1060.59	730.24	3.41	0.28
10560	330.64	1060.73	730.09	3.41	0.28
10570	330.92	1060.88	729.95	3.41	0.28
10580	331.21	1061.02	729.81	3.41	0.28
10590	331.49	1061.16	729.67	3.41	0.28
10600	331.78	1061.30	729.52	3.41	0.28
10610	332.06	1061.44	729.38	3.41	0.28
10620	332.34	1061.58	729.24	3.41	0.28
10630	332.63	1061.72	729.10	3.41	0.28
10640	332.91	1061.86	728.95	3.41	0.28
10650	333.19	1062.01	728.81	3.41	0.28
10660	333.48	1062.15	728.67	3.41	0.28
10670	333.76	1062.29	728.53	3.41	0.28
10680	334.05	1062.43	728.38	3.41	0.28
10690	334.33	1062.57	728.24	3.41	0.28
10700	334.61	1062.71	728.10	3.41	0.28
10710	334.89	1062.85	727.96	3.41	0.28
10720	335.18	1062.99	727.81	3.41	0.28
10730	335.46	1063.13	727.67	3.41	0.28
10740	335.74	1063.27	727.53	3.41	0.28

	10750	336.03	1063.41	727.38	3.41	0.28
	10760	336.31	1063.55	727.24	3.41	0.28
	10770	336.59	1063.69	727.10	3.41	0.28
	10780	336.88	1063.83	726.96	3.41	0.28
	10790	337.16	1063.97	726.81	3.41	0.28
3 Hour	10800	337.44	1064.11	726.67	3.41	0.28
	10810	337.72	1064.25	726.53	3.41	0.28
	10820	338.01	1064.39	726.38	3.41	0.28
	10830	338.29	1064.53	726.24	3.41	0.28
	10840	338.57	1064.67	726.10	3.41	0.28
	10850	338.85	1064.81	725.96	3.41	0.28
	10860	339.14	1064.95	725.81	3.41	0.28
	10870	339.42	1065.09	725.67	3.41	0.28
	10880	339.70	1065.23	725.53	3.41	0.28
	10890	339.98	1065.37	725.38	3.41	0.28
	10900	340.27	1065.51	725.24	3.41	0.28
	10910	340.55	1065.65	725.10	3.41	0.28
	10920	340.83	1065.78	724.95	3.41	0.28
	10930	341.11	1065.92	724.81	3.41	0.28
	10940	341.39	1066.06	724.67	3.41	0.28
	10950	341.68	1066.20	724.53	3.41	0.28
	10960	341.96	1066.34	724.38	3.41	0.28
	10970	342.24	1066.48	724.24	3.41	0.28
	10980	342.52	1066.62	724.10	3.41	0.28
	10990	342.80	1066.76	723.95	3.41	0.28
	11000	343.08	1066.89	723.81	3.41	0.28
	11010	343.37	1067.03	723.67	3.41	0.28
	11020	343.65	1067.17	723.52	3.41	0.28
	11030	343.93	1067.31	723.38	3.41	0.28
	11040	344.21	1067.45	723.24	3.41	0.28
	11050	344.49	1067.58	723.09	3.41	0.28

11060	344.77	1067.72	722.95	3.41	0.28
11070	345.05	1067.86	722.81	3.41	0.28
11080	345.33	1068.00	722.66	3.41	0.28
11090	345.62	1068.14	722.52	3.41	0.28
11100	345.90	1068.27	722.38	3.41	0.28
11110	346.18	1068.41	722.23	3.41	0.28
11120	346.46	1068.55	722.09	3.41	0.28
11130	346.74	1068.69	721.95	3.41	0.28
11140	347.02	1068.82	721.80	3.41	0.28
11150	347.30	1068.96	721.66	3.41	0.28
11160	347.58	1069.10	721.52	3.41	0.28
11170	347.86	1069.24	721.37	3.41	0.28
11180	348.14	1069.37	721.23	3.41	0.28
11190	348.42	1069.51	721.09	3.41	0.28
11200	348.70	1069.65	720.94	3.41	0.28
11210	348.98	1069.78	720.80	3.41	0.28
11220	349.26	1069.92	720.66	3.41	0.28
11230	349.55	1070.06	720.51	3.41	0.28
11240	349.83	1070.19	720.37	3.41	0.28
11250	350.11	1070.33	720.23	3.41	0.28
11260	350.39	1070.47	720.08	3.41	0.28
11270	350.67	1070.60	719.94	3.41	0.28
11280	350.95	1070.74	719.79	3.41	0.28
11290	351.23	1070.88	719.65	3.41	0.28
11300	351.51	1071.01	719.51	3.41	0.28
11310	351.79	1071.15	719.36	3.41	0.28
11320	352.07	1071.29	719.22	3.41	0.28
11330	352.35	1071.42	719.08	3.41	0.28
11340	352.62	1071.56	718.93	3.41	0.28
11350	352.90	1071.69	718.79	3.41	0.28
11360	353.18	1071.83	718.65	3.41	0.28

11370	353.46	1071.97	718.50	3.41	0.28
11380	353.74	1072.10	718.36	3.41	0.28
11390	354.02	1072.24	718.21	3.41	0.28
11400	354.30	1072.37	718.07	3.41	0.28
11410	354.58	1072.51	717.93	3.41	0.28
11420	354.86	1072.64	717.78	3.41	0.28
11430	355.14	1072.78	717.64	3.41	0.28
11440	355.42	1072.91	717.50	3.41	0.28
11450	355.70	1073.05	717.35	3.41	0.28
11460	355.98	1073.18	717.21	3.41	0.28
11470	356.26	1073.32	717.06	3.41	0.28
11480	356.53	1073.45	716.92	3.41	0.28
11490	356.81	1073.59	716.78	3.41	0.28
11500	357.09	1073.72	716.63	3.41	0.28
11510	357.37	1073.86	716.49	3.41	0.28
11520	357.65	1073.99	716.34	3.41	0.28
11530	357.93	1074.13	716.20	3.41	0.28
11540	358.21	1074.26	716.06	3.41	0.28
11550	358.49	1074.40	715.91	3.41	0.28
11560	358.76	1074.53	715.77	3.41	0.28
11570	359.04	1074.67	715.63	3.41	0.28
11580	359.32	1074.80	715.48	3.41	0.28
11590	359.60	1074.94	715.34	3.41	0.28
11600	359.88	1075.07	715.19	3.41	0.28
11610	360.16	1075.21	715.05	3.41	0.28
11620	360.43	1075.34	714.91	3.41	0.28
11630	360.71	1075.47	714.76	3.41	0.28
11640	360.99	1075.61	714.62	3.41	0.28
11650	361.27	1075.74	714.47	3.41	0.28
11660	361.55	1075.88	714.33	3.41	0.28
11670	361.82	1076.01	714.19	3.41	0.28

11680	362.10	1076.14	714.04	3.41	0.28
11690	362.38	1076.28	713.90	3.41	0.28
11700	362.66	1076.41	713.75	3.41	0.28
11710	362.93	1076.54	713.61	3.41	0.28
11720	363.21	1076.68	713.47	3.41	0.28
11730	363.49	1076.81	713.32	3.41	0.28
11740	363.77	1076.94	713.18	3.41	0.28
11750	364.04	1077.08	713.03	3.41	0.28
11760	364.32	1077.21	712.89	3.41	0.28
11770	364.60	1077.34	712.75	3.41	0.28
11780	364.88	1077.48	712.60	3.41	0.28
11790	365.15	1077.61	712.46	3.41	0.28
11800	365.43	1077.74	712.31	3.41	0.28
11810	365.71	1077.88	712.17	3.41	0.28
11820	365.98	1078.01	712.02	3.41	0.28
11830	366.26	1078.14	711.88	3.41	0.28
11840	366.54	1078.27	711.74	3.41	0.28
11850	366.82	1078.41	711.59	3.41	0.28
11860	367.09	1078.54	711.45	3.41	0.28
11870	367.37	1078.67	711.30	3.41	0.28
11880	367.65	1078.81	711.16	3.41	0.28
11890	367.92	1078.94	711.02	3.41	0.28
11900	368.20	1079.07	710.87	3.41	0.28
11910	368.48	1079.20	710.73	3.41	0.28
11920	368.75	1079.33	710.58	3.41	0.28
11930	369.03	1079.47	710.44	3.41	0.28
11940	369.30	1079.60	710.29	3.41	0.28
11950	369.58	1079.73	710.15	3.41	0.28
11960	369.86	1079.86	710.01	3.41	0.28
11970	370.13	1080.00	709.86	3.41	0.28
11980	370.41	1080.13	709.72	3.41	0.28

11990	370.69	1080.26	709.57	3.41	0.28
12000	370.96	1080.39	709.43	3.41	0.28
12010	371.24	1080.52	709.29	3.41	0.28
12020	371.51	1080.65	709.14	3.41	0.28
12030	371.79	1080.79	709.00	3.41	0.28
12040	372.06	1080.92	708.85	3.41	0.28
12050	372.34	1081.05	708.71	3.41	0.28
12060	372.62	1081.18	708.56	3.41	0.28
12070	372.89	1081.31	708.42	3.41	0.28
12080	373.17	1081.44	708.28	3.41	0.28
12090	373.44	1081.57	708.13	3.41	0.28
12100	373.72	1081.71	707.99	3.41	0.28
12110	373.99	1081.84	707.84	3.41	0.28
12120	374.27	1081.97	707.70	3.41	0.28
12130	374.54	1082.10	707.55	3.41	0.28
12140	374.82	1082.23	707.41	3.41	0.28
12150	375.09	1082.36	707.27	3.41	0.28
12160	375.37	1082.49	707.12	3.41	0.28
12170	375.64	1082.62	706.98	3.41	0.27
12180	375.92	1082.75	706.83	3.41	0.27
12190	376.19	1082.88	706.69	3.41	0.27
12200	376.47	1083.01	706.54	3.41	0.27
12210	376.74	1083.14	706.40	3.41	0.27
12220	377.02	1083.27	706.26	3.41	0.27
12230	377.29	1083.41	706.11	3.41	0.27
12240	377.57	1083.54	705.97	3.41	0.27
12250	377.84	1083.67	705.82	3.41	0.27
12260	378.12	1083.80	705.68	3.41	0.27
12270	378.39	1083.93	705.53	3.41	0.27
12280	378.67	1084.06	705.39	3.41	0.27
12290	378.94	1084.19	705.25	3.41	0.27

12300	379.22	1084.32	705.10	3.41	0.27
12310	379.49	1084.45	704.96	3.41	0.27
12320	379.76	1084.58	704.81	3.41	0.27
12330	380.04	1084.71	704.67	3.41	0.27
12340	380.31	1084.84	704.52	3.41	0.27
12350	380.59	1084.97	704.38	3.41	0.27
12360	380.86	1085.10	704.23	3.41	0.27
12370	381.13	1085.22	704.09	3.41	0.27
12380	381.41	1085.35	703.95	3.41	0.27
12390	381.68	1085.48	703.80	3.41	0.27
12400	381.96	1085.61	703.66	3.41	0.27
12410	382.23	1085.74	703.51	3.41	0.27
12420	382.50	1085.87	703.37	3.41	0.27
12430	382.78	1086.00	703.22	3.41	0.27
12440	383.05	1086.13	703.08	3.41	0.27
12450	383.32	1086.26	702.94	3.41	0.27
12460	383.60	1086.39	702.79	3.41	0.27
12470	383.87	1086.52	702.65	3.41	0.27
12480	384.14	1086.65	702.50	3.41	0.27
12490	384.42	1086.78	702.36	3.41	0.27
12500	384.69	1086.90	702.21	3.41	0.27
12510	384.96	1087.03	702.07	3.41	0.27
12520	385.24	1087.16	701.93	3.41	0.27
12530	385.51	1087.29	701.78	3.41	0.27
12540	385.78	1087.42	701.64	3.41	0.27
12550	386.06	1087.55	701.49	3.41	0.27
12560	386.33	1087.68	701.35	3.41	0.27
12570	386.60	1087.80	701.20	3.41	0.27
12580	386.87	1087.93	701.06	3.41	0.27
12590	387.15	1088.06	700.91	3.41	0.27
12600	387.42	1088.19	700.77	3.41	0.27

12610	387.69	1088.32	700.63	3.41	0.27
12620	387.96	1088.45	700.48	3.41	0.27
12630	388.24	1088.57	700.34	3.41	0.27
12640	388.51	1088.70	700.19	3.41	0.27
12650	388.78	1088.83	700.05	3.41	0.27
12660	389.05	1088.96	699.90	3.41	0.27
12670	389.33	1089.09	699.76	3.41	0.27
12680	389.60	1089.21	699.62	3.41	0.27
12690	389.87	1089.34	699.47	3.41	0.27
12700	390.14	1089.47	699.33	3.41	0.27
12710	390.41	1089.60	699.18	3.41	0.27
12720	390.69	1089.72	699.04	3.41	0.27
12730	390.96	1089.85	698.89	3.41	0.27
12740	391.23	1089.98	698.75	3.41	0.27
12750	391.50	1090.11	698.61	3.41	0.27
12760	391.77	1090.23	698.46	3.41	0.27
12770	392.05	1090.36	698.32	3.41	0.27
12780	392.32	1090.49	698.17	3.41	0.27
12790	392.59	1090.62	698.03	3.41	0.27
12800	392.86	1090.74	697.88	3.41	0.27
12810	393.13	1090.87	697.74	3.41	0.27
12820	393.40	1091.00	697.59	3.41	0.27
12830	393.67	1091.12	697.45	3.41	0.27
12840	393.95	1091.25	697.31	3.41	0.27
12850	394.22	1091.38	697.16	3.41	0.27
12860	394.49	1091.51	697.02	3.41	0.27
12870	394.76	1091.63	696.87	3.41	0.27
12880	395.03	1091.76	696.73	3.41	0.27
12890	395.30	1091.89	696.58	3.41	0.27
12900	395.57	1092.01	696.44	3.41	0.27
12910	395.84	1092.14	696.30	3.41	0.27

12920	396.11	1092.27	696.15	3.41	0.27
12930	396.38	1092.39	696.01	3.41	0.27
12940	396.66	1092.52	695.86	3.41	0.27
12950	396.93	1092.64	695.72	3.41	0.27
12960	397.20	1092.77	695.57	3.41	0.27
12970	397.47	1092.90	695.43	3.41	0.27
12980	397.74	1093.02	695.29	3.41	0.27
12990	398.01	1093.15	695.14	3.41	0.27
13000	398.28	1093.28	695.00	3.41	0.27
13010	398.55	1093.40	694.85	3.41	0.27
13020	398.82	1093.53	694.71	3.41	0.27
13030	399.09	1093.65	694.56	3.41	0.27
13040	399.36	1093.78	694.42	3.41	0.27
13050	399.63	1093.91	694.28	3.41	0.27
13060	399.90	1094.03	694.13	3.41	0.27
13070	400.17	1094.16	693.99	3.41	0.27
13080	400.44	1094.28	693.84	3.41	0.27
13090	400.71	1094.41	693.70	3.41	0.27
13100	400.98	1094.53	693.55	3.41	0.27
13110	401.25	1094.66	693.41	3.41	0.27
13120	401.52	1094.79	693.27	3.41	0.27
13130	401.79	1094.91	693.12	3.41	0.27
13140	402.06	1095.04	692.98	3.41	0.27
13150	402.33	1095.16	692.83	3.41	0.27
13160	402.60	1095.29	692.69	3.41	0.27
13170	402.87	1095.41	692.55	3.41	0.27
13180	403.14	1095.54	692.40	3.41	0.27
13190	403.41	1095.66	692.26	3.41	0.27
13200	403.67	1095.79	692.11	3.41	0.27
13210	403.94	1095.91	691.97	3.41	0.27
13220	404.21	1096.04	691.82	3.41	0.27

13230	404.48	1096.16	691.68	3.41	0.27
13240	404.75	1096.29	691.54	3.41	0.27
13250	405.02	1096.41	691.39	3.41	0.27
13260	405.29	1096.54	691.25	3.41	0.27
13270	405.56	1096.66	691.10	3.41	0.27
13280	405.83	1096.79	690.96	3.41	0.27
13290	406.10	1096.91	690.82	3.41	0.27
13300	406.36	1097.03	690.67	3.41	0.27
13310	406.63	1097.16	690.53	3.41	0.27
13320	406.90	1097.28	690.38	3.41	0.27
13330	407.17	1097.41	690.24	3.41	0.27
13340	407.44	1097.53	690.09	3.41	0.27
13350	407.71	1097.66	689.95	3.41	0.27
13360	407.98	1097.78	689.81	3.41	0.27
13370	408.24	1097.91	689.66	3.41	0.27
13380	408.51	1098.03	689.52	3.41	0.27
13390	408.78	1098.15	689.37	3.41	0.27
13400	409.05	1098.28	689.23	3.41	0.27
13410	409.32	1098.40	689.09	3.41	0.27
13420	409.58	1098.53	688.94	3.41	0.27
13430	409.85	1098.65	688.80	3.41	0.27
13440	410.12	1098.77	688.65	3.41	0.27
13450	410.39	1098.90	688.51	3.41	0.27
13460	410.66	1099.02	688.37	3.41	0.27
13470	410.92	1099.14	688.22	3.41	0.27
13480	411.19	1099.27	688.08	3.41	0.27
13490	411.46	1099.39	687.93	3.41	0.27
13500	411.73	1099.52	687.79	3.41	0.27
13510	411.99	1099.64	687.65	3.41	0.27
13520	412.26	1099.76	687.50	3.41	0.27
13530	412.53	1099.89	687.36	3.41	0.27

13540	412.80	1100.01	687.21	3.41	0.27	
13550	413.06	1100.13	687.07	3.41	0.27	
13560	413.33	1100.26	686.93	3.41	0.27	
13570	413.60	1100.38	686.78	3.41	0.27	
13580	413.87	1100.50	686.64	3.41	0.27	3 Hour 46 Minutes 30 seconds
13590	414.13	1100.63	686.49	3.41	0.27	
13600	414.40	1100.75	686.35	3.41	0.27	
13610	414.67	1100.87	686.21	3.41	0.27	
13620	414.93	1100.99	686.06	3.41	0.27	
13630	415.20	1101.12	685.92	3.41	0.27	
13640	415.47	1101.24	685.77	3.41	0.27	
13650	415.73	1101.36	685.63	3.41	0.27	
13660	416.00	1101.49	685.49	3.41	0.27	
13670	416.27	1101.61	685.34	3.41	0.27	
13680	416.53	1101.73	685.20	3.41	0.27	
13690	416.80	1101.85	685.05	3.41	0.27	
13700	417.07	1101.98	684.91	3.41	0.27	
13710	417.33	1102.10	684.77	3.41	0.27	
13720	417.60	1102.22	684.62	3.41	0.27	
13730	417.87	1102.34	684.48	3.41	0.27	
13740	418.13	1102.47	684.33	3.41	0.27	
13750	418.40	1102.59	684.19	3.41	0.27	
13760	418.66	1102.71	684.05	3.41	0.27	
13770	418.93	1102.83	683.90	3.41	0.27	
13780	419.20	1102.96	683.76	3.41	0.27	
13790	419.46	1103.08	683.62	3.41	0.27	
13800	419.73	1103.20	683.47	3.41	0.27	
13810	419.99	1103.32	683.33	3.41	0.27	
13820	420.26	1103.44	683.18	3.41	0.27	
13830	420.53	1103.57	683.04	3.41	0.27	

13840	420.79	1103.69	682.90	3.41	0.27
13850	421.06	1103.81	682.75	3.41	0.27
13860	421.32	1103.93	682.61	3.41	0.27
13870	421.59	1104.05	682.47	3.41	0.27
13880	421.85	1104.17	682.32	3.41	0.27
13890	422.12	1104.30	682.18	3.41	0.27
13900	422.38	1104.42	682.03	3.41	0.27
13910	422.65	1104.54	681.89	3.41	0.27
13920	422.91	1104.66	681.75	3.41	0.27
13930	423.18	1104.78	681.60	3.41	0.27
13940	423.44	1104.90	681.46	3.41	0.27
13950	423.71	1105.03	681.32	3.41	0.27
13960	423.98	1105.15	681.17	3.41	0.26
13970	424.24	1105.27	681.03	3.41	0.26
13980	424.50	1105.39	680.88	3.41	0.26
13990	424.77	1105.51	680.74	3.41	0.26
14000	425.03	1105.63	680.60	3.41	0.26
14010	425.30	1105.75	680.45	3.41	0.26
14020	425.56	1105.87	680.31	3.41	0.26
14030	425.83	1106.00	680.17	3.41	0.26
14040	426.09	1106.12	680.02	3.41	0.26
14050	426.36	1106.24	679.88	3.41	0.26
14060	426.62	1106.36	679.74	3.41	0.26
14070	426.89	1106.48	679.59	3.41	0.26
14080	427.15	1106.60	679.45	3.41	0.26
14090	427.42	1106.72	679.31	3.41	0.26
14100	427.68	1106.84	679.16	3.41	0.26
14110	427.94	1106.96	679.02	3.41	0.26
14120	428.21	1107.08	678.87	3.41	0.26
14130	428.47	1107.20	678.73	3.41	0.26
14140	428.74	1107.32	678.59	3.41	0.26

	14150	429.00	1107.44	678.44	3.41	0.26
	14160	429.26	1107.56	678.30	3.41	0.26
	14170	429.53	1107.68	678.16	3.41	0.26
	14180	429.79	1107.81	678.01	3.41	0.26
	14190	430.05	1107.93	677.87	3.41	0.26
	14200	430.32	1108.05	677.73	3.41	0.26
	14210	430.58	1108.17	677.58	3.41	0.26
	14220	430.85	1108.29	677.44	3.41	0.26
	14230	431.11	1108.41	677.30	3.41	0.26
	14240	431.37	1108.53	677.15	3.41	0.26
	14250	431.64	1108.65	677.01	3.41	0.26
	14260	431.90	1108.77	676.87	3.41	0.26
	14270	432.16	1108.89	676.72	3.41	0.26
	14280	432.43	1109.01	676.58	3.41	0.26
	14290	432.69	1109.13	676.44	3.41	0.26
	14300	432.95	1109.25	676.29	3.41	0.26
	14310	433.22	1109.37	676.15	3.41	0.26
	14320	433.48	1109.49	676.01	3.41	0.26
	14330	433.74	1109.60	675.86	3.41	0.26
	14340	434.00	1109.72	675.72	3.41	0.26
	14350	434.27	1109.84	675.58	3.41	0.26
	14360	434.53	1109.96	675.43	3.41	0.26
	14370	434.79	1110.08	675.29	3.41	0.26
	14380	435.06	1110.20	675.15	3.41	0.26
	14390	435.32	1110.32	675.00	3.41	0.26
4 Hour	14400	435.58	1110.44	674.86	3.41	0.26

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